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Department of
Water Resources

Bulletin No. 160-74

The California Water Plan Outlook in 1974

November 1974
Summary Report

The
Resources Agency

Norman B. Livermore, Jr.
Secretary for Resources

State of California

Ronald Reagan
Governor

Department of
Water Resources

John R. Teerink
Director

FOREWORD

Water development has done more to enhance the economy and environment of California than any of man's other activities. From a hostile climate has come the livelihood of 20.9 million people and a major portion of the nation's food supply. California today is the result of the planning and management of its water resources by local, state, and federal agencies. California tomorrow will also depend on continued wise resource management but is challenged by increasingly complex issues that will affect the quality of life. Water development is a part of these interrelated issues and must be viewed in a broader context than in the past. An affluent society with its water demands satiated can afford to consider a larger value system.

Momentous events and trends have occurred during the past four years since our last statewide water resource assessment was made. Some of these events and trends have already affected the water picture in definable ways, while the effects of others are yet to mature. Some major examples are the establishment of stringent goals for water quality improvement and waste management, the substantial new demands for cooling water for thermal electric power plants, the reservation of one-fourth of the State's surface water resources in a Wild and Scenic River System, the increasing worldwide demand for agricultural products, widespread litigation seeking delay or curtailment of water development programs, and the escalating costs of energy.

While these and additional events have occurred, other significant trends have continued that also affect the State's water resources. Population has continued to increase, but at a rate less than during the 1960s, reflecting the national trend, and thereby stretching our presently developed water supplies. Irrigated agriculture has continued to increase at about the same rate as during the previous reporting period.

On a statewide basis, the California water outlook is favorable. There are, however, areas facing distress and some uncertainties in the future that will require corrective action. The continued increase of salinity in many of the local ground water basins and in water from the Colorado River will be detrimental to many water users. The continued overdraft, currently over one and one-half million acre-feet per year, in the San Joaquin Valley will have a permanent adverse economic effect on the user and will deplete some portions of the basin. Conveyance facilities are necessary to bring developed water supplies to the areas of need in the valley.

The inland siting of thermal electric power plants will impose a significant water requirement on water deficient areas of the State. To meet this requirement every effort should be made to use our poorer quality water supplies such as agricultural drainage and other waste water to the extent feasible. Where agricultural waste water can be used, the drainage disposal problem could be reduced.

Current litigation, if successful, will have a serious adverse effect on several areas of the State. Alternatives to projects in contention are limited and costly. The full ramifications of these law suits cannot be determined at this time.

Thorough study needs to be given to alternatives that would continue to stretch our water supplies. The reclamation of waste water, including demineralization of brackish water, appears to be the most promising today. While research and development of alternatives continues, it is incumbent on all users to achieve more efficient use of the water supplies now available. Several significant policy issues relating to water resource management need careful and thoughtful public and legislative consideration if we are to most effectively meet our future water needs.

John R. Teerink

JOHN R. TEERINK, *Director*
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INTRODUCTION

Bulletin No. 160–74 is the third in a series of reports updating the California Water Plan, originally published in 1957 as Department of Water Resources Bulletin No. 3. The California Water Plan is a comprehensive master plan to guide and coordinate the use of California's water resources for all beneficial purposes to meet present and future needs in all parts of the state. The plan is not a specific blueprint for construction but is, rather, a flexible pattern which can provide information and guidance relating to the use of the state's water resources, its future water requirements, and sources of water supply for California.

In this bulletin, the Department of Water Resources has departed from the previous practice of developing a single forecast of future water requirements, and has used for the first time a concept of "alternative futures". Under this concept, four different estimates of future water requirements are developed, each relating to different scenerios as to future conditions and events that affect water use and demands.

Data collected by the Department of Water Resources since publication of Bulletin No. 160–70 four years ago show that water use in California between 1967 and 1972 has increased a moderate 1.4 million acre-feet, or some 4 percent, corresponding generally to a moderate population increase of 1.4 million people, or 7 percent, and an increase in irrigated area of 300,000 acres or 4 percent. Analysis of present and past conditions, together with studies and estimates of future conditions—using the alternative futures approach—indicates the following outlook for water resources management in California.

The Outlook in 1974

General

1. The status of developed and available water supplies compared to present demands for water is still favorable—the situation affords time for consideration of all alternative sources for future water supply, including techniques for more efficient use of water to reduce demands. This outlook is premised on completion of Auburn Dam on the American River, New Melones Dam on the Stanislaus River, and Warm Springs Dam on Dry Creek in the Russian River Basin, and the Peripheral Canal being constructed and in operation by 1980.

2. How far into the future this condition will extend depends on the completion of additional conveyance facilities needed to deliver already regulated supplies to various service areas in the State.

3. The extent to which available supplies will cover future requirements is considerably less certain in 1974 than it appeared to be in 1970 because of highly significant events and trends that have occurred during the last four years—major factors being the establishment of additional water requirements for water quality improvement and salinity control; the movement toward siting of power plants at inland locations rather than on the coast, also leading to a substantial additional water requirement; and the worldwide leap in demand for agricultural products.

4. In addition, no new water projects that would develop additional supplies of any significance have been authorized, either by state, federal, or local agencies in California during the past four years, and virtually every attempt to begin construction of previously authorized projects or units of such projects has met with litigation seeking to delay or stop such construction—a condition which, along with the wild river legislation and the coastal zone initiative, clearly reflects a widespread public interest and concern with protection and preservation of the natural environment.

5. The quality of the State's water supply is generally quite satisfactory, with the significant exception of the Colorado River and some localized ground water problems, and may be expected to be maintained and improved as the result of the basin plans for water quality management currently being developed by the State Water Resources Control Board.

6. While the urban areas of the State should experience no significant or extensive water shortages during the next 20 years, the prospects of providing water for any large expansion of irrigated agriculture in California to meet increased demands for food and fiber worldwide are not considered optimistic under the general conditions prevailing at the present time.

Concerning Growth

1. In 1974 the population of California was 20.9 million people, reflecting a continued slowing in growth rates, and it may range from a low of 23.6 to a high of 27.4 million by 1990, or an increase of 13 to 31 percent. By 2020, the population may range from 26.5 to 43.3 million, or an increase of 27 to 107 percent.

2. Of the total state area of 100 million acres, urban development currently occupies 2.6 million acres and may increase to between 2.9 and 3.3 million by 1990. Urban land use in 2020 may range from 3.2 to 4.4 million acres—still less than 5 percent of the total area of the State.

3. Irrigated agriculture increased at an average rate of 60,000 acres per year from about 8.5 million acres in 1967 to about 8.8 million in 1972. Irrigated area may range between 9.2 and 10.2 million acres by 1990, an increase of 5 to 16 percent. In 2020, irrigated land may range from 9.4 million to 11.4 million acres, an increase from 7 to 29 percent. The Department of Water Resources' land classification surveys show 22 million acres of irrigable land in California.

Concerning Water Demands

1. Urban water use is now about 5 million acre-feet annually, and future demands are expected to range from 6.2 to 7.1 million acre-feet in 1990, an increase of 22 to 41 percent. By 2020, urban use may range from 7.2 to 11.4 million acre-feet. Urban water use today accounts for about 13 percent of total water use in the State.

2. Present agricultural water use is 32 million acre-feet of applied water annually, or about 85 percent of total water use in the State. Demands for agricultural water in 1990 are expected to range from 34 million to 38 million acre-feet, an increase of from 7 to 19 percent. By 2020, agricultural water demands may range from 35 to 42 million acre-feet annually.

3. If two-thirds of the projected increase in thermal electrical generation is located at inland sites, up to 400,000 acre-feet of cooling water will be required by 1990, and as much as 1.1 million acre-feet could be required by 2020.

4. Total annual applied water demands for all purposes in California are projected to increase from the present 37 million acre-feet, and may range from 41 to 46 million acre-feet in 1990, an increase from 10 to 24 percent annually. By 2020, the total applied water demands may range from 43 to 55 million acre-feet annually.

5. Net water demands in California, which reflect the opportunities to reuse return flows, are projected to increase from the 1972 level of 31 million acre-feet annually, and may range from 34 to 38 million acre-feet by 1990, an increase of 11 to 23 percent. By 2020, total net water demands may range from 36 to 46 million acre-feet annually.

6. With full use of presently foreseen supplies, the supplemental water requirements are expected to range from 1.6 million to 3.8 million acre-feet annually by 1990, and from 2.6 to 9.6 million acre-feet annually by 2020.

Concerning Present Water Supplies

1. California's present water needs are being met by existing state, federal, and local projects, and in some areas, especially the San Joaquin Valley, by overdrafting ground water supplies. More water is available from the existing projects than is being used now, and this reserve can be used to satisfy increasing demands for a number of years, providing necessary conveyance facilities are constructed in a timely manner. One such facility is the Peripheral Canal which will provide conveyance of water for several regions. Other facilities are mentioned in the regional outlooks later in this section.

2. Supplemental water requirements currently average 2.4 million acre-feet per year and are being met primarily through ground water overdraft. The major overdrafted areas are in the San Joaquin Valley, the Central Coast, and Southern California.

3. Total overdraft of ground water basins has decreased in the past four years by about 500,000 acre-feet per year, due to new water brought into the western San Joaquin Valley by the State Water Project and the San Luis Division of the Central Valley Project, thus replacing to some extent previous ground water use. Remaining overdrafts, of which the largest is 1.4 million acre-feet on the east side of the San Joaquin Valley, are not considered permanent sources of water supply. The Cross Valley Canal, under construction by the Kern County Water Agency, will alleviate some of the overdraft in the San Joaquin Valley. Further, a possible mid-valley canal, being studied by the Department of Water Resources and the Bureau of Reclamation, could provide additional alleviation of part of the remaining San Joaquin Valley overdraft.

4. Intentionally reclaimed waste water furnished about 180,000 acre-feet of usable water supply in 1972, most of which was for agricultural irrigation. An additional 530,000 acre-feet of waste water was indirectly reclaimed, returned to the surface and ground water supply and reused.

5. In 1974, virtually no water supply from desalting plants was being used in California, and none at all was furnished from geothermal sources.

Concerning New Water Supplies

1. The location, character of streamflow, and present stage of development of California's surface water resources are such that the only areas in the State where there is any substantial physical potential for development of additional water supplies are in the north coastal area and the Sacramento River Basin. More than 25 percent (18 million acre-feet) of the total stream runoff in California is set aside and not available for water supply development under existing law for wild and scenic rivers in the north coastal area (although the law does require the Department of Water Resources to report in 1985 on the need for water supply and flood control projects on the Eel River and its tributaries). There is a potential for additional development of water in the Sacramento Basin, although such development will be costly because the more economical sites have already been developed.

2. Conjunctive use of ground water basins and surface supplies can achieve more effective use of existing surface water supplies and would help conserve water that would otherwise spill from surface reservoirs during periods of high water. Additional study and exploration of the State's ground water basins are needed to adequately assess the potential for conserving additional surface water resources through conjunctive operation.

3. The California Aqueduct will have excess capacity for several years that could be used to convey surplus water from Northern California for recharge of overdrawn ground water basins in Southern California.

4. Reclamation of waste water, including highly saline agricultural waste water, may provide an important source of industrial water, particularly for cooling in power plants. Reservations regarding the safety of reclaimed water from a health standpoint greatly limit its use for human consumption and restrict projecting future use for municipal water supply purposes. To adequately evaluate the role of waste water reclamation in meeting the supplemental demands, the Department of Water Resources is participating in projects of applied research.

5. Desalting of sea water on a large scale does not currently appear practical due to high costs and extremely large energy requirements. Desalting may be used for a variety of smaller applications, however, over the next 10 to 30 years, particularly to treat brackish waste water for use as cooling water in power plants. In coastal communities requiring supplemental water supplies, there may be limited possibilities for desalting sea water by distillation. Inland communities with brackish ground water supplies may find the membrane processes (reverse osmosis and electrodialysis) practical.

6. Geothermal resources in the Imperial Valley could provides California with additional energy, and possibly water supplies. These could help meet local municipal and industrial water demands or might be blended with Colorado River water to reduce the salinity of water supplies from the river. To this date however, it has not been demonstrated that development of geothermal water supplies is feasible, either from an economic or environmental point of view.

7. There are several operational weather modification programs in California and in other states. It has not been possible to determine the extent to which a consistent increase in precipitation and streamflow can be attained. Several studies and pilot projects are underway but their success is problematical. Consequently, it is not prudent at this time to rely on weather modification as a feasible source of future water supply. In addition, there are as yet unresolved problems of environmental effects and legal questions.

Concerning Regional Water Supply and Demand

1. *North Coastal.* Overall water supplies are abundant, amounting to nearly 40 percent of the total water resources of the State. However, there are scattered local shortages during the dry season when streams are low. In the interior (upper Klamath River Basin including the Shasta and Scott Rivers) present supplies are nearly completely used and significant expansion would require additional water development.

Only minor increases from present water demands are projected for the region in 1990, most of which are expected to be met from increased ground water pumping and remaining surface supplies. The minor increase in supplemental demand is mostly due to increases in wildlife requirements.

2. *San Francisco Bay.* This region presently has enough water to take care of its requirements, except for a few scattered areas in the North Bay and Russian River basins. Overall water supplies appear adequate for 1990, but the distribution of supplies does not correspond with the pattern of projected demand. Therefore, a supplemental demand of from 30,000 to 80,000 acre-feet per year is indicated, primarily in Santa Clara, Marin, and Napa Counties. The near future supply assumes completion of Warm Springs Dam and Reservoir. If that water supply of 115,000 acre-feet is not available, major shortages in Sonoma County also would be expected by 1990. Completion of the North Bay Aqueduct of the State Water Project will provide capacity for an additional 12,500 acre-feet annually for Napa County.

3. *Central Coastal.* Water demands in this region presently exceed dependable supplies by about 140,000 acre-feet, per year, with the difference showing up as ground water overdraft. This has resulted in salinity intrusion in certain coastal aquifers. The quality of ground water is poor in the area around the City of Santa Barbara and some locations along the Santa Maria River. New supplies to Santa Barbara and San Luis Obispo Counties from the Coastal Aqueduct of the State Water Project will help meet demands, but projected increases in 1990 water demands would leave a shortage between 200,000 to 280,000 acre-feet per year. The bulk of the shortage would be in the northern portion of the region, including the Salinas Valley and the service area of the authorized San Felipe Division of the Central Valley Project.

4. *South Coastal.* Water demands in 1972 had begun to outstrip the supplies available from sources other than the State Water Project. New supplies from the State Water Project should be more than adequate to meet 1990 water demands, even with the projected reduction of about 780,000 acre-feet per year in Colorado River supplies including some reallocations for power plant cooling in the desert areas. The increase in State Water Project supply and its

substitution in part for Colorado River water should markedly lower the dissolved salts content of Southern California water supplies. Indicated annual 1990 demands range from 650,000 to 1,030,000 acre-feet less than 1990 total water supplies assuming the full contractual commitments of the State Water Project are available to the region.

5. *Sacramento Basin.* Although overall supplies in this region appear adequate, not all locations have sufficient dependable water supplies at present. The indicated current annual deficit is estimated to be 240,000 acre-feet and could increase to as much as 500,000 acre-feet by 1990 for the highest demand projection, or could be slightly less than current levels for the lowest demand projection. Most of the projected supplemental demand in 1990 is expected to occur on the west side of the Sacramento Valley and in several upland basins.

Significant additions to present water facilities include completion of the Tehama-Colusa Canal in the Sacramento Valley and Indian Valley Reservoir on Cache Creek, both currently under construction.

6. *Delta-Central Sierra.* Estimated 1972 supplemental demand was about 120,000 acre-feet per year, mostly in the Folsom South Canal service area in Sacramento and San Joaquin Counties. Completion of the Folsom-South Canal and possibly a Hood-Clay intertie from the Sacramento River will meet this demand. Other supplemental demands ranging from 80,000 to 220,000 acre-feet would remain. Completion of the North Bay Aqueduct of the State Water Project will enable 43,000 acre-feet annually to be supplied Solano County from the Delta.

7. *San Joaquin Basin.* The estimated present ground water overdraft in this region is about 250,000 acre-feet per year, mainly in Madera, southeastern Merced, and eastern Stanislaus Counties. The assumed additional Central Valley Project supply of New Melones Reservoir, plus some additional use of other sources, is not expected to completely end the overdraft. Supplemental demands ranging from 130,000 to 670,000 acre-feet are projected for 1990.

8. *Tulare Basin.* Estimated 1972 ground water overdraft was slightly over 1,300,000 acre-feet per year, significantly less than the 1,800,000 acre-feet amount in 1967. The improvement is due to new water supplies from the Central Valley Project and the State Water Project to service areas on the west side of the basin, with some 1,500,000 acre-feet provided in 1972. By 1990 projected deliveries would be increased by about another 1,300,000 acre-feet per year, but increases in demand and continued overdraft in areas not served by state and federal facilities would still leave supplemental demands or continuing ground water overdrafts ranging from 920,000 to 1,920,000 acre-feet per year. A possible mid-valley canal could convey surplus water to the east side of the basin to partially alleviate overdrafted ground water conditions.

9. *North Lahontan.* Water demands by 1990 could range from a slight decrease to a minor increase over the present net demands of 430,000 acre-feet per year. Some of the current deficiency in firm water supply, about 40,000 acre-feet, is expected to be met by continuing ground water development. There is projected a 1990 supplemental irrigation demand of about 20,000 acre-feet per year. The high cost of water development, however, will make it difficult to meet this requirement.

10. *South Lahontan.* Estimated present annual ground water overdraft amounts to about 120,000 acre-feet. Projected State Water Project entitlement supplies, if delivered in 1990, could completely eliminate the current overdraft and could add from 70,000 to 100,000 acre-feet per year to underground storage in the Antelope Valley-Mojave River areas.

11. *Colorado Desert.* Only modest increases of 130,000 to 150,000 acre-feet per year in agricultural and urban applied water demands are projected for this region in 1990. The estimated 1972 annual ground water overdraft of almost 40,000 acre-feet could be mostly eliminated by use of State Water Project supplies. The only significant new type of demand would be that for power plant cooling which could range from 40,000 to 130,000 acre-feet per year in 1990, part of which is expected to be served from the Colorado River entitlement of the Metropolitan Water District of Southern California.

Concerning Alternative Futures

1. None of the four alternative futures presented in this bulletin was designed to represent a most probable future. If such a projection were to be developed, it would most likely result in a statewide water demand somewhere within the range of alternative futures II and III.

2. Selection of a future(s) as a basis for making a decision should reflect the degree of flexibility to change a decision. In other words, as long as it is not necessary to make a final decision, alternative futures should be examined and, when it becomes necessary to adopt a course of action, a single future must be selected.

3. In evaluating actions to meet the short range 1990 needs, the Department of Water Resources concludes that alternative future II is a reasonable basis since it would be unwise to risk water shortages due to unplanned rates of growth. In evaluating actions to meet 2020 needs the Department concludes that alternative future III provides flexibility yet is a reasonable basis as use of this alternative future minimizes the likelihood of oversizing of facilities and overcommitment of resources.

California's Water Resources

California's natural water supplies are derived from an average annual precipitation of 200 million acre-feet—the equivalent of more than 65 trillion gallons. About 65 percent of this precipitation is consumed through evaporation and transpiration by trees, plants, and other vegetation (Figure 1). The remaining 35 percent comprises the State's average annual runoff of 71 million acre-feet.

Water information compiled by the Department of Water Resources and presented in this report is shown by 11 hydrologic study areas covering California, Figure 2. Average runoff in the hydrologic areas is shown in Figure 3. The wide disparity in runoff, both from year to year and between major drainage areas, creates the need for the storage and conveyance of surface water and the extensive use of ground water. As shown in Figure 3, the greatest amounts of runoff are available in areas with the fewest people, i.e., the North Coastal area and the Sacramento Basin. As California has grown, its surface water systems have been expanded to large-scale transfer systems, involving the storage and transportation of water almost the entire length of the State.

A continuing major water problem today is the maintenance of a proper balance between the use of the State's water resources and protection and enhancement of the natural environment. Prior to the 1960s, environmental benefits for the preservation of cultural resources and aesthetic areas, including open and green space, wild rivers, and wilderness regions, were not usually included in water project planning. Many such benefits were difficult to identify and are still difficult to measure because they cannot be assigned a value, and the technique of cost and benefit analysis to determine relative value of a proposed project is no longer adequate. Accordingly, to reflect today's widespread concern for the natural environment, water resources planning has been broadened to include consideration of aesthetic and ecological effects.

State Responsibility for Water Development

California's responsibility for the development and wise use of her water resources is set forth in various sections of the California Water Code. The Department of Water Resources and the State Water Resources Control Board each are assigned specific duties in the Code. The Board regulates activities that affect quality and rights to use of the waters of the State. Water Code Section 10005, in addition to establishing the California Water Plan, assigns the Department of Water Resources the responsibility for updating and

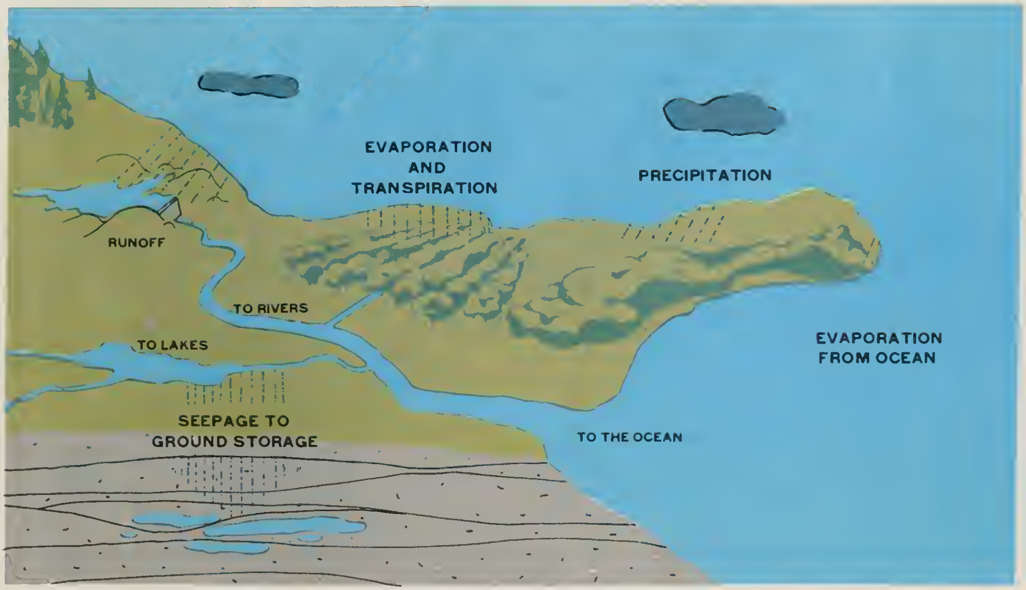


Figure 1. The Hydrologic Cycle

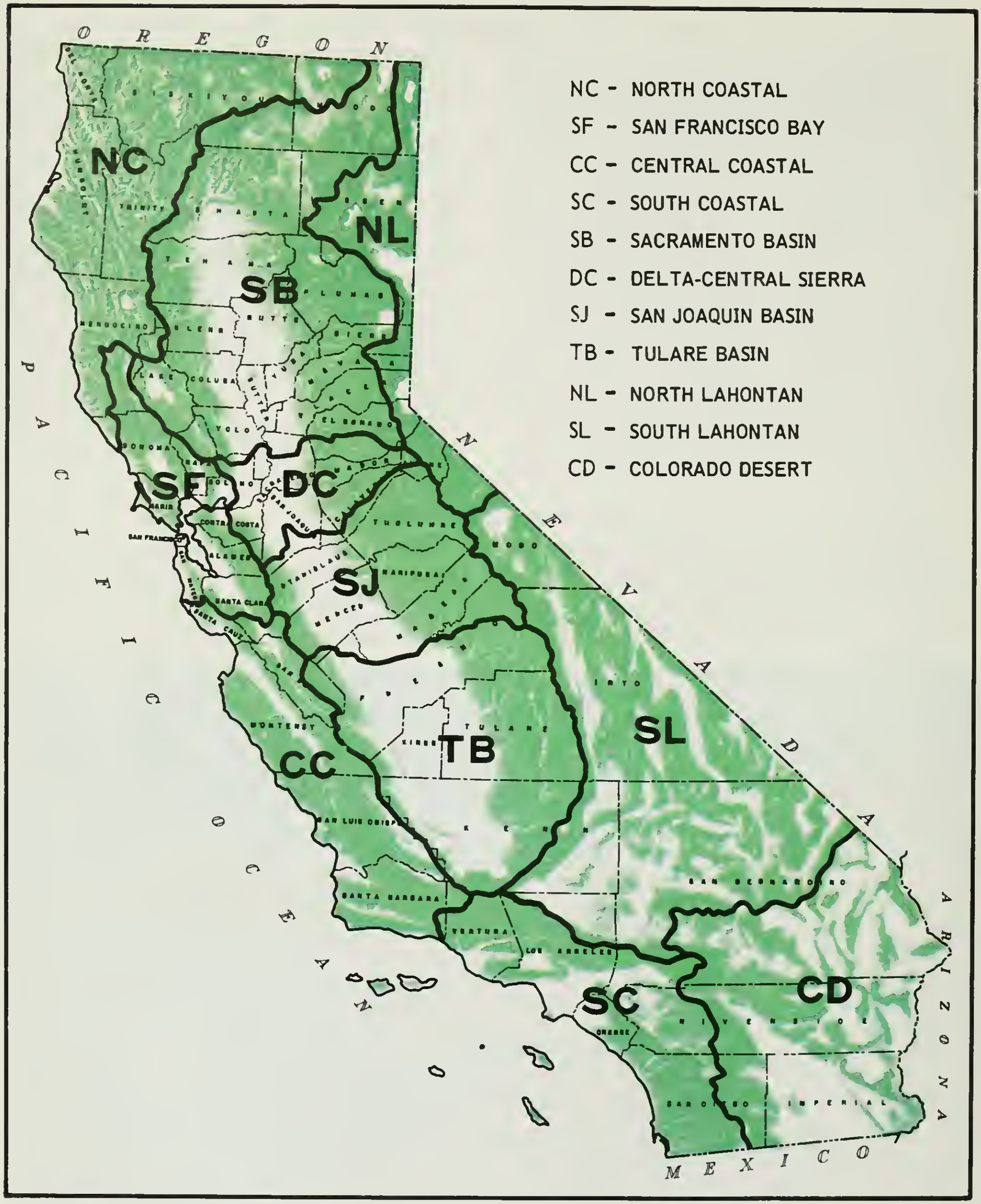


Figure 2. Hydrologic Study Areas of California

supplementing the Plan. The Department carries out this responsibility through a statewide planning program, which guides the selection of the most favorable pattern for use of the State's water resources, considering all reasonable alternative courses of action. Such alternatives are evaluated on the basis of technical feasibility and economic, social, and institutional factors. The program comprises:

- Periodic reassessment of existing and future demands for water for all uses in each of the hydrologic study areas of California
- Periodic reassessment of local water resources, water uses, and the magnitude and timing of the need for additional water supplies that cannot be provided locally.
- Appraisal of various alternative sources of water—ground water, surface water, reclaimed waste water, desalting, geothermal resources, etc.,—to meet future demands in areas of water deficiency.
- Determination of the need for protection and preservation of water resources in keeping with protection and enhancement of the environment.
- Evaluation of water development plans.

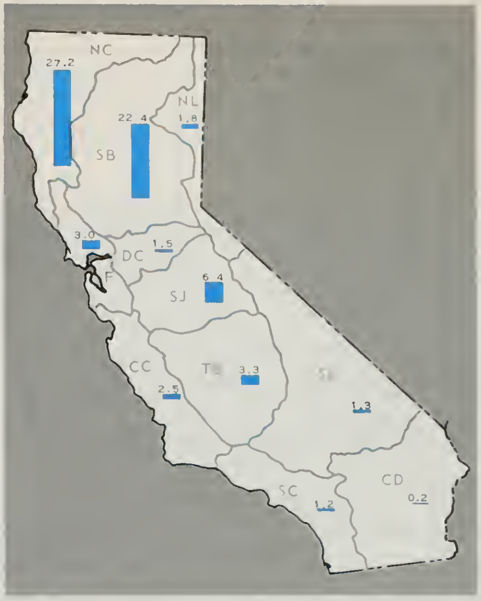


Figure 3. Average Annual Runoff in Million Acre-Feet

Organization of Bulletin 160-74

Bulletin No. 160-74 and its summary report have the same format, which consists of six chapters. Chapter 1 discusses historic and recent events in water resources planning and development in California, including recent environmental planning, measures to enhance water quality, and the recent interest and close involvement of the public in environmental enhancement. Chapter 1 also touches on a recent National Water Commission report, which indicates possible forthcoming changes in U. S. water policies. Finally, the chapter reports on California's cooperative activities with federal water agencies and other western states, and briefly describes recent trends in land use planning and controls.

Chapter 2 presents a discussion of important water-policy issues for consideration by legislators, administrators and the public. Chapter 3 presents alternative future projections—of population, agriculture, and electrical energy. In addition, Chapter 3 discusses the trends and influences that affect other water-related needs, such as (a) recreation, fish, and wildlife, (b) environmental quality, (c) water quality, and (d) flood control.

In Chapter 4, the alternative future projections presented in Chapter 3 are discussed in terms of future water demands.

Chapter 5 discusses potential supplemental sources of water supply and water quality planning. Chapter 6 relates the alternative future projections of water demand presented in Chapter 4 to existing developed supplies and gives estimates of future supplemental water demands.

Pine Flat Reservoir, constructed by the U.S. Army Corps of Engineers

U.S. Army Corps of Engineers photo

I. HISTORIC AND RECENT EVENTS

During the past 125 years, the development of California's water, which began with the diversion of gold-mining and irrigation supplies from streams by individual miners, farmers, and ranchers, has culminated in large interbasin transfer systems, such as the federal Central Valley Project and the California State Water Project. Although these large projects are more widely known, the efforts of local water agencies have long dominated water development in the State. Plate 1 (Page 28) shows major features of the State Water Project and federal and local projects.

Water Resources Development in California

The construction of large dams began in California during the 1880s. Whereas the early projects were chiefly intended to provide water for local use, the concept of long-distance transfer of water supplies came into being not long after 1900. Los Angeles began diverting water from the Owens River, some 240 miles to the northeast, in 1916; water is conveyed to the city from Owens Valley through the twin-pipeline Los Angeles Aqueduct. Since 1934, San Francisco has imported much of its water through its Hetch Hetchy Aqueduct from the Hetch Hetchy Project on the Tuolumne River, 150 miles east of San Francisco.

Similarly, the East Bay Municipal Utility District, which serves Oakland, Alameda, and other east bay communities, obtains water from Pardee Reservoir on the Mokelumne River, some 85 miles east of Oakland. The Metropolitan Water District of Southern California diverts water from the Colorado River and transports it 240 miles to Los Angeles through the Colorado River Aqueduct.

The first comprehensive statewide investigations of California's water resources were conducted by the State Engineer beginning in 1920. Ten years later, the results of these investigations were published as Division of Water Resources[1] Bulletin No. 25, "Report to Legislature of 1931 on State Water Plan". This report and subsequent studies lead to state authorization of the Central Valley Project.

Federal Water Projects in California

The State Water Plan, which envisioned transfers of surplus water from the Sacramento River Basin to water-deficient areas of the State, particularly the upper San Francisco Bay area and the San Joaquin Valley, eventually formed the basis for the Federal Central Valley Project (CVP). A key CVP feature (Plate 1) is Shasta Dam and Lake, near the junction of the Sacramento, McCloud, and Pit Rivers, which conserves surplus flows in these rivers, regulates flood flows in the Central Valley, enhances navigation on the Sacramento River, controls salinity in the Sacramento-San Joaquin Delta, and produces hydroelectric energy. Near Tracy, water is pumped into the 120-mile-long Delta-Mendota Canal for use along the west side of the San Joaquin Valley and to replace San Joaquin River water diverted at Millerton Lake.

An important CVP feature is Trinity Dam and Clair Engle Lake on the Trinity River, which, in combination with Whiskeytown Reservoir on a tributary of the Sacramento River, furnishes hydroelectric energy and north coastal water for use in the Central Valley.

Another key CVP feature is Friant Dam (Millerton Lake) on the San Joaquin River in Fresno County and the Madera and Friant-Kern Canals, which serve the east side of the San Joaquin Valley in Madera, Fresno, Tulare, and Kern Counties. Still another important CVP unit is Folsom Dam (Folsom Lake) near Sacramento, which regulates flood flows on the American River and furnishes hydroelectric energy to the CVP network.

In 1967, the Bureau of Reclamation completed the San Luis Division addition to the CVP. The joint federal-state San Luis Dam and Pumping Plant is also a key feature of the California State Water Project. Other CVP works under construction include Auburn Dame on the North Fork American River, the Folsom-South Canal, and the San Luis Drain. The CVP is currently delivering some six million acre-feet of water to local agencies.

The U. S. Army Corps of Engineers is also involved in water development in California. Principal flood control projects include Pine Flat and Isabella Reservoirs in the Tulare Basin, Lake Mendocino on the Russian River, and an extensive system of channels and reservoirs in the Sacramento Valley, South Coast, and other areas of the State. Recently completed projects include Martis Dam and Reservoir on Martis Creek in Nevada County and Mojave Dam on the Mojave River. Projects under construction include New Melones Dam on the Stanislaus River, Warm Springs Dam on the Russian River in Sonoma County, Hidden Dam on the Fresno River, and Buchanan Dam on the Chowchilla River.

[1] of the Department of Public Works; now the Department of Water Resources.

California State Water Project

The California State Water Project (Plate 1)—designated in the California Water Plan as the initial unit for state construction—is now delivering water to 24 water-service agencies in the Feather River area, San Francisco Bay area, San Joaquin Valley, and Southern California. The May 1973 dedication of Perris Dam in Riverside County marked the completion of the initial facilities of the Project, the largest single water delivery system in the world.

Construction of the State Water Project began in 1957 with the relocation of highways and railroads near the present site of Lake Oroville, where water is stored for distribution to drier areas of the State. Today the principal Project facilities include 23 dams and reservoirs, 16 pumping plants, 5 powerplants, and the 444-mile-long main line of the California Aqueduct, along with its four main branch lines—the South Bay Aqeuduct, the West Branch, and portions of the Coastal Branch, and the North Bay Aqueduct. The Peripheral Canal is being designed for service to begin in 1980.

Transition to the Present

The ten years following publication of the California Water Plan was a decade of swift population growth and rapidly increasing demands for water. In 1966, the Department of Water Resources published Bulletin 160-66, "Implementation of the California Water Plan". This bulletin reported that the population of California—soon to be the most populous state in the nation—had increased almost 45 percent, from 13 million to almost 19 million since 1955. On the basis of this performance, California's population was projected to exceed 35 million by 1990 and to top 54 million in 2020.

Bulletin 160-66 forecast that by 1990, statewide irrigated acreage would increase to 9.5 million acres, and to 10.8 million acres by 2020. Under these circumstances, substantial additions to the authorized water conservation facilities of the State Water Project and federal Central Valley Project, as well as other water supply systems, would be needed by 1980.

By 1970, however, the spectacular population growth rate of the 1940s, 1950s, and early 1960s had slowed down markedly due to reductions in both births and immigration. Accordingly, Bulletin No. 160-70 [1], the second in the Bulletin 160 series, forecast a 1990 population of 29 million and a 2020 population of 45 million. On the basis of these revised predictions, irrigated acreage was predicted to increase to 9.3 million acres by 1990 and to 9.6 million acres by 2020. Bulletin No. 160-70 also predicted that more time would be available to develop new water supplies and that additional conservation facilities would not be needed until some time during the 1990s.

A number of significant events have occurred in the last four years, some of which have tended to place an increased burden on the State's water resources and some of which have directed more attention to those factors affecting the future use of water resources. At the federal level, the National Water Commission has published probably the most comprehensive report ever seen on water management; a National Environmental Policy Act has been adopted; Congress has given considerable attention to a National Land Use Policy; and principles and standards have been established by the Water Resources Council and adopted by the President that add environmental quality as an objective for planning.

At the state level California has adopted a Wild and Scenic Rivers Act which dedicates about one-fourth of the State's surface water flow to scenic and recreational use; an Environmental Quality Act similar to the federal legislation has been adopted; and several major administrative decisions concerning water rights have focused attention on natural environmental and esthetic uses of water.

National Water Commission Report

A recent report issued by the National Water Commission indicates that U.S. water resources policies may soon be changed, particularly the method of financing water projects. The report, "Water Policies For the Future" (June 1973), is the most comprehensive analysis of federal water policies and practices, and the most far-reaching in its recommendations, ever published. The Commission, which was established by Congress in 1968 and terminated in 1973, was directed to ". . . review present and anticipated national water resource problems, making such projections of water requirements as may be necessary and identifying alternative methods of meeting those requirements . . . and (2) consider economic and social consequences of water resource development . . . and (3) advise on specific matters . . . referred to it by the President and the Water Resources Council."

The report advocates increased planning at local or regional levels supported by federal funding. Furthermore, the Commission strongly urges that responsibility for financing water projects should be shifted to those who will benefit from them. In keeping with this idea, the Commission's summary report suggests the following five new "waternomics" (sic) policies:

1. *Inland Waterways.* "Users of inland waterways should pay costs of operation and maintenance. On future waterway projects, beneficiaries should repay construction costs with interest."

[1] "Water For California, The California Water Plan, Outlook in 1970," December 1970.

2. *Water Supply Projects.* "Future water supply projects for municipal, industrial, and agricultural water should only be undertaken if all costs of construction, operation and maintenance can be recovered from beneficiaries."

3. *Agricultural Land Enhancement Programs.* "Subsidized reclamation programs place an unfair burden on taxpayers. Agricultural water projects, such as irrigation of arid lands, drainage of wetlands, and flood protection for bottom lands should be paid for in the price of the crops."

4. *Flood Control.* "Costs of flood control projects such as reservoirs, dams, and levees to protect flood plains often exceed the cost of developing flood-free land. Costs of flood control projects should be paid for by the beneficiaries."

5. *Recreational Benefits.* "Where federal tax money is used to provide recreational benefits the users should repay costs through direct user fees and excise taxes on some recreational equipment."

Adoption of all these recommendations would appear to almost remove the Federal Government from the water resources picture. However, the report also states that ". . . there will be a continuing need for vigilant federal oversight. . . . The Federal Government should encourage regional, state and local programs, and assume responsibility when other levels of government fail to perform." Furthermore, the report also suggests joint federal and nonfederal financing of water projects as a method that will "provide incentives for the selection of efficient projects . . . and that would require projects to be in the proper locations, at the proper time, to provide the proper services in the proper amounts." The report concludes that ". . . cost-sharing policies should be equitable, with project beneficiaries bearing proportionate shares of project costs."

The State of California agreed with some of the National Water Commission's conclusions and recommendations and disagreed with others. The State considered unrealistic: (a) the assumption of greatly increased prices for water, and (b) assumed shifts of agricultural production from irrigated to nonirrigated lands. The State also disagreed with economic criteria proposed for interbasin transfers of water.

Environmental Events

Today, the State is vitally concerned with the quality of the environment and, along with the Federal Government, has taken a number of steps to better incorporate this concern into all future water resources planning. Planning for water development is a critical element in environmental protection because of the direct effect of water projects on the ecosystem. A proposed water project can no longer be evaluated solely on the basis of a cost and benefit analysis but, instead, must include consideration and evaluation of its effects on the environment.

Environmental Legislation

Bulletin No. 160-70 reported that the 1970s had been declared "the decade of the environment" by both the National Congress and the California Legislature. Just prior to 1970, Congress had enacted the National Environmental Policy Act of 1969 to prevent damage to the natural environment and to protect the nation's natural resources. The federal Wild and Scenic Rivers Act sets for the basic principle that certain rivers of the Nation are to be preserved in a free-flowing condition and protected for the enjoyment of present and future generations. Named in the Act was the Middle Fork Feather River, one of the first to be so designated.

In 1972, the California Legislature passed a California Wild and Scenic Rivers Act. The Act placed eight California rivers in a state system and provided that they be classified as wild, scenic, and recreational. These are the entire Smith River and major portions of the Klamath, Trinity, Scott, Salmon, Eel, Van Duzen, and the north fork and lower main stem of the American River. Except for the Eel River, the Act precludes all planning and construction of projects that would directly affect the free-flowing condition of the rivers.

The law directs that after 1984, the Department of Water Resources will report to the Legislature on the results of studies of the need for flood control and water supply conservation facilities on the Eel. This report will be the basis for legislative hearings to determine whether portions of the Eel River should be removed from the system.

The National Environmental Policy Act requires all federal agencies, in every recommendation for a project that would significantly affect the quality of the human environment, to include an "Environmental Impact Statement." This is a detailed statement of the possible adverse environmental effects of the proposed project and is required not only with proposals by federal agencies but also with proposals by other agencies that would include federal financing.

A corollary law at the state level is the *California Environmental Quality Act of 1970.* This Act requires state and local agencies to include an "Environmental Impact Report" on all projects they propose to carry out or approve. In addition, the Act requires state agencies to include funds for environmental protection in all budgetary requests.

Porter-Cologne Water Quality Control Act

The Porter-Cologne Water Quality Control Act of 1970 strengthened the State Water Quality Act of 1949 and required implementation of a statewide program for control of the quality of all water resources of the State. To assist in this program, the people of California appproved the Clean Water Bond Law in 1970, which enabled the sale of $250 million in general obligation bonds to assist local government agencies in correcting and preventing water pollution. Some $6 million was allocated to the State Water Resources Control Board for the development of plans for water quality control in 16 planning basins covering the entire State. The Department of Water Resources is preparing plans for four of the basins for the State Board. Each plan is designed to preserve and enhance water quality and to protect beneficial uses over the next 25 to 30 years.

Public Involvement

Much of the recent environmental legislation reflects firm public support. Public opinion polls taken during the late 1960s and early 1970s showed strong sentiment toward environmental protection, and all levels of government—Congress, the California Legislature, and local boards and commissions—responded to the apparent concern of their constituents. Citizens are also voicing their concern more directly. For example, in 1972, California voters approved an initiative which established the California Coastal Zone Protection Act. The Act established a State Commission and six regional commissions who are responsible for protection and preservation of the coastal environment. The State Commission, with input from the regional bodies, must submit a coastline protection plan to the Legislature by January 1976. After the plan has been approved by the Legislature, all development and construction in designated coastline areas will have to meet the criteria established by the plan. In the meantime, all development within 1,000 yards of the ocean must be approved by the appropriate regional commission.

Water Rights Decisions

Three recent decisions by the State Water Resources Control Board, Decisions 1379, 1400, and 1422, have imposed significant environmental constraints on water development in California. All three decisions significantly affect the operation of existing water projects as well as future planning. All three are under court review.

Decision 1379 will require greater outflows from the Sacramento-San Joaquin Delta than those considered in previous planning and will reduce the quantity of water available for delivery to the service areas of the Central Valley Project and State Water Project. In effect, the decision establishes water quality standards in the Sacramento-San Joaquin Delta, and directs the Bureau of Reclamation and the Department of Water Resources to maintain these standards. This will require either reducing project diversions or releasing stored water. The objective of the standards is to protect agricultural, municipal and industrial, and fishery uses in the Delta.

Decision 1400, which applies to Auburn Reservoir on the American River, requires greatly increased flows—from 1,250 to 1,500 cubic feet per second (cfs)—rather than 250 to 500 cfs—for fishery and recreation uses in the American River from Nimbus Dam to its confluence with the Sacramento River. The Bureau of Reclamation had planned to divert much of the flow of the American to service areas in Sacramento and San Joaquin Counties through the Folsom-South Canal. Decision 1400 will enhance fishery and recreational benefits in the American River between Folsom Dam and Sacramento.

Decision 1422 orders the Bureau of Reclamation to limit storage in New Melones Reservoir on the Stanislaus River to slightly more than half the total reservoir capacity until a specific need for additional water service for consumptive purposes is demonstrated. The storage limitation will extend the use of a popular "whitewater" area and at the same time provide sufficient yield to satisfy demands for local service area irrigation, water quality control, and fishery and wildlife benefits. Hydroelectric energy generation and recreation aspects of the project will be curtailed.

Litigation

The courts have played an increased role in water resources development during the last several years. Most litigation against agencies planning or constructing water projects has been initiated by individuals or groups who believe that such projects would adversely affect the environment or that the project plans included insufficient environmental protection. Many of the lawsuits were brought under the National Environmental Policy Act or the California Environmental Quality Act.

In California, although lawsuits have delayed some projects, no water projects have been totally abandoned because of litigation alone. However, many current lawsuits are still in various stages of trial or pretrial or have been appealed to higher courts, and some of these will not be resolved for several years.

State-Federal and Interstate Activities

California's ability to provide adequate water for future needs is in part dependent on the State's relationship with agencies of the Federal Government. In another respect its coordination with other western states is also important. California's participation in a number of state-federal and interstate activities is described in some detail in the full report. The activities dealt with include California's cooperation with or participation in:

1. The Western U. S. Water Plan Study, which was undertaken to develop a general plan to meet the future water needs of the western states.

2. Cooperative studies of the salinity of the Colorado River.
3. The Western States Water Council, whose purpose is to provide cooperation in water planning among the states of the West.
4. The California State-Federal Interagency Group, which was established as a forum for exchange of information and resolution of problems among a number of state and federal agencies in California.
5. The Klamath River Basin Compact and the California-Nevada Interstate Compact, under which California cooperates with Oregon and Nevada, respectively, in the administration and use of surface waters common to both states.

Land Use Planning and Controls

Land-use controls are not a new concept in California. Federal, state, and local governments, as well as public initiative action, have all contributed a variety of control mechanisms. Recently, however, principally in response to environmental concerns, the number of such control measures has been increasing. The controls imposed on land development by the National Environmental Policy Act and the California Environmental Quality Act of 1970 have already been described. A recent dramatic example of public initiative is the California Coastal Zone Protection Act of 1972 (described in a previous paragraph). In a recent report on land use and associated environmental issues, the Council of Environmental Quality, established by the National Environmental Policy Act of 1969, described the many new land-use controls as a "quiet revolution."

Federal legislation recently under consideration would have had state governments responsible for (1) establishing a statewide land use planning process within 3 years of passage, (2) developing an adequate state land-use program within 5 years of passage, and (3) establishing an intergovernmental advisory council consisting of local governmental officials. Under the legislation, states would have been required to have the power to regulate development around important major facilities, such as airports, freeway interchanges, etc., and to regulate real estate development 10 miles beyond the boundaries of a "Standard Metropolitan Statistical Area." These bills died in Congress, but similar legislation will probably be enacted in the future.

In California, recent legislative concern has been directed toward establishing a responsible state agency to assist the Legislature in designating areas of critical concern and establishing rules and regulations for land development within those areas.

II. KEY WATER POLICY ISSUES

A significant aspect of the greatly expanded public concern for natural environmental conditions is the need for greater consideration of interrelationships of actions, "trade-offs", and secondary effects. The need to evaluate the interrelationships, and frequently even their existence, is not always recognized. The complex interrelationships need to be understood to avoid simplistic or partial solutions to water problems.

The following discussions outline some of the current water policy issues that need thorough consideration. In some cases adequate data are not available to make complete assessments of the interrelationships currently considered important. Awareness of these and the likely direction of the effects is, however, very important to sound decisions. Every effort should be made to avoid actions that produce unexpected and adverse results. All of the issues relate to changing public attitudes that affect or are affected by water development and management. The principal cause for the changes relates to revised views on protection and enhancement of the natural environment.

Over the past quarter century, the technology of economic analysis as applied in the planning, formulation, and design of government-sponsored water resources development has reached a high level of sophistication, particularly as compared with the analysis of other government-sponsored programs. This technology, based largely on economic criteria, has its critics and its difficulties. When properly and conscientiously applied it provided a tangible basis for decision making in connection with implementation of major water resources development and the allocation of the costs among beneficiaries.

Within recent years, however, this approach to the decision making process has been seriously challenged by those who contend that preservation and enhancement of the natural environment, and social considerations, are of primary concern in connection with any development-oriented undertaking. These considerations are highly qualitative, judgment oriented, and not readily adaptable to quantitative expression or economic dimensioning. When included in water project development they result in benefits and costs which many significantly affect the cost of other products and services.

In an expanding economy under conditions of increasing population, maintenance of the status quo, or the "no project alternative", usually represents a cost in itself, since the products and services which society demands must be supplied from a more costly alternative. Indeed, the "environmental movement" and the increasing awareness and concern on the part of the general public for the natural environment and esthetics appear to be side effects or results of increasing economic affluence in a large sector of society.

Although environmental and esthetic goals involve economic aspects, it is not necessary that these considerations be forced into a rigorous economic framework. Care must be taken, however, to adopt a reasonable balance between economic factors and subjective factors to provide opportunity for the economically handicapped portion of society to increase its level of economic affluence to a point where it can participate in the natural environmental and esthetic amenities of California. Such an approach would recognize the impact of water management actions on the environment as well as recognize the economic and social impact of development. There is need for a straightforward, workable basis for formulating and evaluating water resources development, and for allocating the costs of such development among all beneficiaries, including those for whom the natural environmental and esthetic considerations are enhanced.

The issues presented in this chapter have significant potential impact on the public and most have received public attention. Most have been extensively reviewed and discussed in various forums including the workshops held by the Department of Water Resources in the preparation of this bulletin. While the subjects have received wide attention, the ramifications of the courses of action have not always received the attention necessary to develop public policy and decisions.

Cooling Water for Electric Energy Production

The cooling water policy issue arises because limitations on locating power plants on the coast are creating a substantial previously unplanned-for demand on inland water resources. Significant resource trade-offs and costs result from the coastal limitations.

In recent decades most of the increased demand for electric energy in California has been met by constructing thermal electric plants. Although the remaining hydroelectric potential is significant, pollution-free, and nonconsumptive of fuels (as pointed out in Department of Water Resources' Bulletin No. 194, "Hydroelectric Energy Potential in California") the majority of future energy requirements must still be met by thermal generating plants. Thermal plants require some high quality water for steam generation, which is frequently obtained by distillation, and much larger quantities of cooling water to recondense the steam and to remove approximately 50 to 60 percent of the heat which cannot be converted to electricity due to natural heat exchange limitations. This cooling water is either passed through the plant and discharged back into its source or recycled through cooling towers where heat is removed by evaporation.

Thermal electric plants located along the Pacific Ocean or its bays and estuaries take advantage of the large volume of cold water available and use once-through cooling systems. Concerns about the marine environment, the esthetics of coastal plants, and the safety of structures against earthquakes, however, have greatly restricted further construction of new plants along the coast during the past few years. The present trend is toward location of new thermal plants at inland sites. Plants in these areas will require recirculation of the cooling water, most of which must come from fresh water resources. The number of new plants which will be constructed at inland sites will depend on many factors but it is possible that the cooling water demands may range between 300,000 and 400,000 acre-feet annually by the year 1990. Even more water might be required in later years, although technological advances may improve cooling methods and energy conservation programs may slow the rate of growth in demand. The U.S. Environmental Protection Agency is currently proposing that all existing plants stop using ocean water for cooling and switch to other sources. To do so would require by 1977 about 200,000 acre-feet of fresh water annually. The Department of Water Resources, State Water Resources Control Board, and the electric utilities have expressed concern to the Environmental Protection Agency that such a requirement is impractical and unnecessary.

Many of the natural environmental concerns about coastal sites apply equally well to inland sites. While there are impacts on marine resources from use of ocean water for cooling, the development of additional surface water supplies for inland plants will also have environmental impacts on fresh water fish and wildlife resources. Similarly, concern with the esthetics and scenery on the coast will be translated to analogous concerns at inland locations. Plants at coastal locations using once-through cooling are not as large and imposing as ones located inland with their large cooling towers, which typically are several hundred feet tall if natural draft is used. An alternative to cooling towers would be construction of large ponds, which could be esthetically pleasing but require large areas of land. Consideration is currently being given to using air cooling, in which the cooling water is recirculated through a radiator system similar to that used in an automobile. These costly systems, however, would require very large installations covering large areas in order to provide enough cooling surface, and they also require energy for pumping.

Water for cooling at inland locations, however, can in part be obtained from waste water discharges which may be too brackish to use for other purposes. Waste water that would otherwise be discharged to the ocean that could be used for power plant cooling could result in an overall economic benefit. The cost of electric generation may be somewhat greater than if fresh water is used due to the cost of pretreatment of the water. The cost of disposing of the waste water, however, could be much lower because the volume may be only about one-tenth the initial volume due to the concentrating effect of the evaporative process. In the Central Valley there will be significant quan-

Ocean water cooling at Diablo Canyon Nuclear Power Plant tities of waste water which must otherwise be discharged to the ocean. This water must be collected, treated, and stored for cooling. Some discharges into the Salton Sea may also offer potential for power plant cooling. The level of the Salton Sea would, however, be lowered and the salinity increased. This would have an impact on the fishery resources and the recreation use of the Salton Sea.

A major untapped source of waste water would be the urban discharges to the ocean and its estuaries. Due to safety and environmental considerations, it has been difficult to locate power plants near the metropolitan areas, and the use of urban waste water for cooling would involve extensive collection and transmission facilities.

An additional factor involved in the source of cooling water is the physical advantage of the cold Pacific Ocean over inland water supplies. The ocean water in Northern California is generally 20-25 degrees colder than inland supplies and therefore is a more efficient coolant. The difference in Southern California may be around 10-15 degrees. The increased efficiency of power plants using colder sea water when compared to plants operated inland with warmer waters and evaporative coolers would be equivalent to between 15 and 20 million barrels of oil annually for the additional plants needed by 1990.

Boards and agencies responsible for developing coastal zone and control plans, the Legislature, and the public should be aware of the trade-offs which are involved. The esthetic impact on the coastline should be compared to the trade-off of a highly visible inland site with its massive cooling towers. Waste water in the San Joaquin Valley used for cooling at inland sites might be some of the water now used for Delta salinity control and would have to be offset by fresh water outflow. Until waste water can be collected and adequately treated, it may be necessary in some areas of the state to use fresh water for cooling thus imposing additional stress on the state's water supplies. The coastal site limitations on power plants will create very similar inland problems.

Water Deficiencies

The size and scheduling of future water conservation facilities, particularly for the State Water Project and the Central Valley Project, depend to some degree on the certainty of meeting contractual delivery schedules. If it is not necessary to fully meet the contractual commitments during dry years, the water supply available during "normal" or wet years can be spread out to more users, or the date by which additional conservation facilities are needed for a given service area can be deferred. This latter concept is the basis for suggestions for increasing the yield of the State Water Project and the Central Valley Project by simply expanding the degree of risk in meeting water delivery commitments. The policy issue is whether an increased degree of risk should be borne by water users in order to defer or avoid additional water development. Equitable consideration of any increased risk would involve all water uses, including municipal and industrial users, agriculture, fish and wildlife, recreation, and hydroelectric generation.

The dependable or firm yield of each water project traditionally has been based on the capabilities of that project to furnish water service on some prescribed pattern or schedule during the most severe drought of record. Built into this approach are tempering allowances for reduction of water deliveries in critically dry years. For example, State Water Project contracts with agricultural customers provide for maximum deficiency of up to 50 percent of contractual amounts in any one year and up to 100 percent cumulative deficiency over a seven-year period after which municipal and agricultural users jointly share any further shortages. The practical effect of these deficiency allowances in project planning and design is to build in some degree of risk, but the amount of risk is usually not statistically determined.

For water projects using Northern California water supplies such as the Central Valley Project and the State Water Project, the historic drought which occurred during the six water seasons 1929 through 1934 is the critical period for project water yield studies. This period was the worst sustained drought in the Sacramento River Basin in the 120 years of record in terms of length and severity. The driest single runoff year in the past 100 years was 1924 (1864 was probably slightly drier, based on very limited rainfall records).

The recurrence interval of a six-year drought comparable in severity to the 1929–1934 critical dry period is not known. Estimates range from between 100 and 400 years, and the best estimate at this time is that a similar drought could be expected about once every 200 years on the average. It could occur twice in successive decades, however.

Critics of the traditional "historic critical period" method have suggested that probability methods be used for determining the design size and water yield accomplishment of water resource projects. With the advent of the electronic computer, this approach is possible, but the matter of risk remains. Three aspects need to be evaluated somewhere in this process: (1) assessment of the level of risk built into the traditional approach, an extremely important point to those holding existing contracts for firm yield; (2) the economic effect of water shortages on various types of use; and (3) the degree of risk of water and hydroelectric power shortage which the public is able or willing to accept and the equitable distribution of such risks.

The same water development system might be able to provide more water on the average than the calculated dry period safe yield, if sufficient conveyance capacity existed. Operating in this manner would tend to use all or much of the reservoir carryover reserves during the current year rather than a longer and more conservative carryover as assumed in conventional studies; therefore, the shortages which occur would generally be greater. The average water supply would be increased, but the lack of dependability would also be increased, causing dry year hardships for some water users whose investments may require a firm or dependable supply. Hydroelectric power production would also be reduced in dry years due to lower water levels in reserviors. This would require additional installed capacity in new thermal electric plants.

The sharing of water deficiencies between agencies under drought conditions would be constrained by institutional and legal considerations. Water rights are property rights and there is no legal basis for sharing between users of different basins.

Cost Sharing of Environmental Enhancement

As a general principle of equity, the cost of mitigation, due to the loss of a public resources, such as fish, has been borne by water project beneficiaries. Considerable efforts have been made to compensate for certain unavoidable losses. For example fish hatcheries have been constructed to replace the loss of fish spawning areas due to dam construction. These have been accepted as project costs. There has not, however, been a corresponding degree of concern with cost sharing for the benefits received when enhancement occurs.

In large federal water projects, such as those on the American River, there are generally many years between the time of authorization of a plan of accomplishments with its corresponding cost-sharing formula and the time the project is completed and in operation. Public pressures for changes in plan or operation to enhance the natural environment are common but generally do not include any proposals for changing the cost-sharing formulas. In some cases large segments of the public can be benefited by project changes, while in other cases only limited numbers of people enjoy the benefits. Frequently, significant benefits incidental to the main purpose of project operation, such as a live summer stream with enough flow to produce "white water" rapids favored for recreation or an esthetically pleasing stream flow, are taken for granted. Intensive public pressures are applied to retain the windfall benefits but little or no indication is made as to what project costs should be assigned to those benefits or how they should be paid for. The result is often long delays in carrying out the water program.

In the Water Rights Decision 1379 of the State Water Resources Control Board provision was made for fishery enhancement. This decision, which calls for mitigation as well as enhancement, establishes certain water quality conditions in the Sacramento-San Joaquin Delta which would in part be dependent on release of stored water. It would require about 500,000 acre-feet annually of stored water from the State Water Project and the federal Central Valley Project to achieve the prescribed conditions for enhancement.

Release of stored water to the lower American River enhances recreation

To make up the loss of water resulting from the decision would require the construction of a new water storage project in the Upper Sacramento Valley or the North Coast.

Among public works projects, water development undertakings are in the forefront on economic justification, that is, benefits versus costs, and on cost allocations. Over the years legislative acts have identified certain types of project accomplishments which are sufficiently widespread to warrant repayment from general taxes. This was the purpose of the Davis-Dolwig Act which applies only to the State Water Project. For federal water projects provision for enhancement may be included at time of authorization, but great difficulty has arisen when these benefits have been added ex post facto. As the type and scope of environmental amenities expand, public policy on cost sharing has not kept pace, and financing and repayment obligations have been assigned by default. There is a pressing need for further conscious consideration of the degree of general public benefit which could be paid by general taxes, and the extent of direct user repayment by the specific beneficiaries. The process of evaluating public interest in paying for various environmental benefits would identify the relation between benefits and costs and may indicate the need to revise some goals.

Water Quality Improvement

Concern for the quality of the rivers and lakes of the nation has become a major public issue in the last decade. The state and national programs for water quality improvement involve large sums of money and material and human resources, as well as releases of stored fresh water in some cases. The United States is now planning to spend billions of dollars over the next few years for clean water. Grants of up to 75 percent of the cost of waste treatment facilities are available to local communities. In California an additional 12.5 percent can be obtained from the State. These programs are designed to treat wastes from municipalities. They call for secondary treatment of all wastes by 1977, the best practicable treatment by 1983, and elimination of all pollutant discharges to navigable waterways by 1985. There are also requirements for major improvements in industrial waste discharges. Increasing attention is being directed to agricultural return flows. Concern is also being expressed with the loads of pollution which run off from streets and urban areas during storm periods, and means of controlling these wastes are being considered.

Benefits from the quality improvements have generally not been assessed in quantitative terms and compared to the costs, particularly the incremental benefits and costs resulting from varying levels of treatment. The issue of cost effectiveness was raised by the National Water Commission in its report of 1973.

The Federal Water Pollution Control Act calls for a high degree of uniformity in requirements throughout the country. The water supplies, seasonal precipitation patterns, present quality of rivers and lakes, and historic pollution control vary widely, however, and many of the requirements for humid and industrialized eastern states do not fit the California case. Strong water quality control has been in effect in California since the late 1940s, and in 1969 this control was further strengthened with enactment of the Porter-Cologne Water Quality Control Act. This Act establishes as state policy that quality of the water resources of the State shall be protected for the use and enjoyment of people and that activities which affect quality shall be regulated to attain the highest water quality which is reasonable considering all uses of the water and all values involved. These qualified policies call for a balance between various water uses. The general public in its support for better water quality or waste treatment may not take into account the tradeoffs that such a program imposes. This could be in the form of higher taxes or prices for goods and services.

Practically all of the attention has been directed toward the reduction of discharged pollutants. Less attention has been directed toward desirable degrees of water quality in the rivers, lakes, and ground water bodies for beneficial uses. Since these are the sources of water supply for other users, there is a relationship between the quality of the supply and the benefits derived by the subsequent user. In most cases there is a wide range of qualities which are fully satisfactory to meet consumptive urban, industrial, and agricultural needs as well as fish, wildlife, and recreation needs. The incremental savings which may result from providing better quality water within that range may be far less than the costs of providing the incremental improvement. As the quality of the water supply deteriorates, the incremental costs to the user become increasingly greater, and in this range there may be justification for larger expenditures on water treatment.

In addition to the overall question on the appropriate level of water quality achievement, there is the consideration of the payment of costs. Where there is widespread public benefit, it is generally satisfactory to use public taxes. Where identifiable commercial interests are involved, the costs are generally assigned to those interests but these increased costs of production are, in turn, passed on to the product consumers.

Some proposals and requirements for water quality improvement involve releases of stored water from existing or future water projects. Dedication of the yield of projects to this end may mean construction of additional and more costly facilities if other water requirements are to be met. The additional costs would be passed on to a different group of beneficiaries unless special provisions are made for repayment. There may also be environmental costs with additional water development which would be an offset to the environmental enhancement achieved by use of stored water.

It is reasonable that additional consideration be given to all types of benefits of water quality improvement to be certain that benefits equal or exceed costs or offsets. Congress has recognized the need for methods of evaluation and the federal program is being evaluated by the National Commission on Water Quality. The Commission report is due in October 1976 and guidelines from this effort are anticipated.

Water Supplies as a Growth Regulator

There has been increasing activity in recent years to limit population growth by restricting water supplies. Most of these efforts have been at the local community level, but there are those who suggest that the denial of additional water would stop population growth in Southern California and thereby alleviate air quality problems, further congestion, and so on. Water is necessary to support growth as well as the status quo, but it is equally true that the factors influencing growth are many.

In California, a State of over 20 million people, much of the pressures of growth are related directly to natural population increase. Decisions regarding numbers of children are matters of individual family planning and are based on considerations other than the availability of water. There is no evidence that decisions to migrate to or from California or to other areas within the State are made on the basis of an assured water supply. Such movement has been induced principally by climatic, social, or economic reasons. Environmental quality is also becoming a motivating factor and is affecting some growth patterns.

When considering the growth issue recognition should be given that curtailing services such as water supplies may not, in fact, limit growth but induce health hazards, environmental degradation, and other complications. Further, in most Califorina urban areas growth would still be possible where water is in short supply by taking water conservation, reclamation, and reuse measures. Finally, localized moves to control population expansion, if successful, might simply transfer the growth and associated problems to another area.

Government at all levels has mechanisms at its disposal to influence population growth patterns. A broad public policy to do so, however, does not exist. When and if such should occur, the State's water resources can be adjusted to accommodate growth patterns. The more significant hurdles may be legal and institutional. Aside from recent court decisions confirming the right to move, significant changes in water law would be necessary. Government can largely control further development of surface water simply by withholding funds for building projects. The surface water supplies remaining to be developed require large projects to be economically feasible and are generally beyond the means of private individuals or the smaller public agencies. Ground water in California is another matter, however. In all but the adjudicated ground water basins of the State, any local public agency or an individual can construct a well and obtain water for a variety of purposes. Under existing law, the state or federal government has little influence on use of ground water except in those few areas where the basin has been so severely overdrawn that the courts through the adjudicatory process have placed limits on the further withdrawal of ground water. A whole new body of ground water law would be required for the State to be able to designate areas that could not use available ground water to support further development.

Another factor to be considered in limiting growth would be the payment of costs incurred and obligated in existing water projects that have been sized and constructed to support future growth.

Role of Water Exchanges in Water Management

As California's water supplies become more fully used or reserved for natural environmental uses, such as wild and scenic rivers, it becomes increasingly important to review water rights and management policies. Many changes would involve revised laws, but frequently much can be done within existing laws or with minor modifications. Significant policies, such as water rights, water pricing, water quality, and flexibility of operations, are almost always involved.

There are opportunities for water exchanges which could be considered to reduce the expenditure of resources to meet future needs and to make more effective use of available resources. Each case will have its own particular problems. It will almost always be necessary to make some financial arrangements, and in many cases there would be water quality considerations. Two key ingredients to agreements appear to be earnest desire by water users to improve the service of their agencies, and mutual economic advantage for each agency. Public interest in the concept would stimulate dormant opportunities. Some past exchanges and potential opportunities that have had some attention are described in the following paragraphs.

Each additional increment of water supply is generally more expensive than previous increments, and frequently long distances between source and area of use are involved. Water supplies are sometimes conveyed through areas which already have adequate supplies or which only received a small additional supply from the system passing through the area. In other cases, areas which have been slow to develop are faced with high costs because supplies originating in or nearby the developing areas have already been appropriated by a downstream or distant area. In some places,

Growth in Southern Califarnia—1954 to 1974 water of excellent quality is used once and discharged to a marine water body and lost. If an alternative and available supply of adequate but lower quality water would suffice, the water of excellent quality might be made available for more than one use.

Possibilities for water exchanges are enhanced when they can be combined with major regional transfer works such as the California Aqueduct of the State Water Project and the Central Valley Project. For example, the Desert Water Agency and the Coachella Valley County Water District have arranged with the Metropolitan Water District of Southern California to take Colorado River water for a few years from the Colorado Aqueduct which goes through their area and, in turn, assign to the Metropolitan Water District their water supply from the State Water Project. This exchange permits the two desert districts to defer a major outlay of funds for a conveyance system to connect with the California Aqueduct until later when demands are greater and the financial base of the districts is larger.

In terms of the quantity of water, the largest exchange in the State involves the Central Valley Project. Water from the Sacramento Valley is conveyed through the Delta-Mendota Canal to Mendota Pool on the San Joaquin River to replace supplies in the river which are diverted at Friant Dam and conveyed southward through the Friant-Kern Canal as far as the Bakersfield area.

Study is being given by the state and federal agencies and the Pacific Gas and Electric Company to increasing dry season in-stream flows in the Eel River below Van Arsdale Dam by using some of the water stored in Lake Pillsbury and diverted by Pacific Gas and Electric to a power plant on the East Fork Russian River. This trade would result in a reduction in power output and some reduction in water supply to the Russian River Basin. Primary benefits would be enhancement of Eel River fisheries and recreation in northern Mendocino and southern Humboldt Counties, plus a possible supplemental irrigation supply in the Eel River Delta.

Where a ground water basin has been adjudicated, as, for example the West Coast Basin in Los Angeles County, exchange of water may occur when surface water is also available. Operation of the basin to reduce sea water intrusion is possible by the reduction in pumping of some overlying owners in exchange for surface water importation. Such exchange also factors in any cost and quality differences between the two sources.

Proposals have also been made to use Los Angeles' Owens Valley Aqueduct Water in communities adjacent to the aqueduct, such as China Lake-Inyokern, in exchange for Northern California water delivered to the City of Los Angeles via the State Water Project and Metropolitan Water District's facilities.

Although the opportunities for exchanges exist, such factors as cost, quality differences, and legal and institutional constraints will often present formidable problems. In the final analysis such exchanges may save conveyance costs but do not obviate the need to develop dependable water supplies.

Public Interest in Agricultural Drainage

Agricultural drainage in the San Joaquin Valley is a problem which could have a major impact on the State's agricultural economy and consequently, upon the economic well-being of a significant portion of the State's population. Some 150,000 acres of presently productive land will become seriously degraded within the next decade unless some corrective measure to remove salt and reduce water tables is developed. An additional 800,000 acres are in jeopardy of a similar fate unless corrected within the next two to five decades. With increasing demands for food, losses of agricultural production in this magnitude would have significant impacts on the economy of the State.

The fundamental problem involves "salt balance" in the San Joaquin Valley where only a part of the salt residue resulting from the consumptive use of local and imported water supplies is discharged from the Valley. The greater portion is simply accumulating in the ground, water and soil. If the productivity of the San Joaquin Valley is to be maintained, this salination process must be stopped and reversed.

The general approach to maintenance of salt balance is to remove the salts from the area in the form of concentrated saline waste water collected as natural drainage or from subsurface drainage systems installed by the irrigators. The San Joaquin River now serves as a conduit for the removal of such waste water in the northern or San Joaquin Basin portion of the Valley. The river also is a source of irrigation water and, at times, the quality is only marginally adequate and further degradation cannot be tolerated. The larger Tulare Lake Basin portion of the San Joaquin Valley is essentially a closed basin with no outlet, and the problem of salt balance in this area is particularly threatening since none of the salts are leaving the basin.

A master drain system for the San Joaquin Valley is an authorized part of the State Water Project, and the Department of Water Resources has made extensive studies of the drainage problem in the Valley and has developed a plan for a master drain system. Difficulties in obtaining repayment contracts with beneficiaries have so far prevented implementation of the plan. The major problem has been that, though a large portion of the San Joaquin Valley contributes to the problem, only those areas which actually suffer damage have thus far been called upon to repay the costs of implementing the drainage plan. Some means is needed to finance and assign responsibility for repayment of the costs of such a system on an expanded repayment base. Benefits to the State in maintaining its number one industry—agriculture, are threatened unless some repayment means are found. The costs would be partially borne by electric power users if thermal electric plants located in the San Joaquin Valley use agricultural drainage water for cooling.

A closely related and significant environmental problem is the mannner of disposing of the saline drainage water. Drainage conveyed to the Sacramento-San Joaquin Delta may require removal of the nutrients to avoid undesirable algae conditions in the Delta channels. The water would, however, provide a portion of the out-flow needed to control intrusion of salinity from the bay system which would otherwise have to be provided from fresh water sources. If the drainage water is ponded in the valley and removed by evaporation, large land areas would be required. Concentrated brine blow-down from power plant cooling would require much less land area. Any inland storage areas would need to be sealed to prevent percolation to ground water and any such plan may only defer an ultimate solution of salt removal. If the water or the salt cannot finally be disposed of at inland facilities or to the ocean through the Delta, it will have to be conveyed by conduit and discharged directly into the ocean at an offshore location. Environmental concerns will be involved in any disposal alternative, and some impact is unavoidable for continuation of the agricultural economy of the State.

Flood Damage Prevention

There are basically two means to prevent flood damages. They are (1) stay out of the way of floods, or (2) keep the flood flows in defined channels either with or without upstream regulatory storage. Both methods have been used throughout the history of California with the greatest emphasis being placed on controlling floods. Although a great deal of money has been spent on structural control measures, such as reservoirs and leveed channels, annual flood damages continue in many unprotected areas. More attention to staying out of the way of floods—flood plain management is being urged.

Significant amounts of public funds and natural resources, as well as control of land use decisions, are involved, and it is increasingly important to give thoughtful consideration to the various aspects of flood damage prevention alternatives.

The nature of California's topography is a major factor in considering this issue. Most of the mountains are geologically young and quite steep. The valleys and plains are composed of the sediments washed down from the mountains. Most of the easily habitable land is a flood plain. Stream channels are naturally inclined to extensive changes in course as sediments build up. Levees and channels works are necessary to keep the floods within reasonable limits, if the flood plain is inhabited.

Staying fully out of the way of floods in California is probably not practical as a complete solution. In some of the mountainous northern California counties, practically all of the "flat" land is in a a flood plain and further economic development would be severely limited if it could not take place in the flood plain, but structural control measures would be required. The desire to maintain streams in their natural state for wildlife or scenic values, particularly in urban areas, will necessitate strong land use controls.

Major flood control reservoirs can adequately reduce most flood peaks, but in all cases they are designed to operate with high release rates to accommodate large inflows from a major storm when the reservoir is nearly full. These high release rates, even though far smaller than the natural flood flows, generally are so infrequent that the public does not recognize that they may occur. Consequently, the flood channel becomes encroached upon by downstream development in the absence of adequate zoning protection. The Sacramento River below Shasta Dam, particularly in the Redding area, and the Santa Ana River in Orange County below Prado Dam are two examples.

Land use control—and flood plain management is a major form of land use control—is, under existing state law, the responsibility of local agencies. Failure to adequately zone, and regulate in accordance therewith, at the local level tends to create laws and programs administered by state and federal governments. To prevent development in floodways in which the State financially assists local agencies to provide rights of way for federal flood control agencies to construct flood control projects, the State has since 1965 under the Cobey-Alquist Act required that the local agency zone and regulate the channel area. For areas identified by the U.S. Department of Housing and Urban Development as having special flood hazards, flood insurance is a requirement to obtain a new or additional loan from a federally insured financial institution, if such insurance is available. After July 1, 1975, loans cannot be made unless the community is participating in the national flood insurance program and insurance is purchased.

In addition to changing public attitudes regarding flood control structures in favor of greater emphasis on flood plain management, the record of unusual flood events continues to lengthen. It indicates that extreme events like the 1964 flood on the Eel River, the new 1974 peak inflow to Shasta Reservoir, or even the 1-in-500-year flood as occurred in Rapid City, South Dakota, in 1972, are possible and it is necessary to plan for increasingly intense storms.

As the State's growth continues, the potential for loss of life and economic investment also grows. The trade-offs between large investment of public funds, flood risk, and the environmental desires to maintain natural channels and wild rivers should be considered in future public policy decisions.

Water Pricing Policy and Its Effect on Demand

To reduce the future quantity of water used by urban areas and irrigated agriculture, suggestions have been made that water prices be raised. Urban users generally pay for water at a flat rate or a decreasing block rate under which the unit costs of successive blocks of water are priced at lower rates, similar to most electric power rates. Irrigation water in federal reclamation projects is priced at less than full costs. Price increases may reduce demand for future irrigation water. Some industries may also be encouraged to use less water or to reuse waste water. There would be related effects which must also be considered in any discussion of the price/demand relationship.

In the development of the State Water Project, an initial determination was made of the overall market for urban and agricultural water, and direct negotiations were undertaken with water agencies acting on behalf of individual customers. Contracts were signed that obligated the water agencies to pay full cost of providing the water, including interest. The aqueduct system was sized and built to convey the contracted for quantities of water. Repayment for the system is the obligation of the agencies. The additional costs of conserving and pumping the water is fixed by contract to the actual costs to the State.

To effect a significant change in agricultural water demands would require a governmental pricing policy for all irrigated area which would result in sufficiently high costs as to eliminate some farming enterprises. Such a governmental policy could not be extended across the agricultural sector under existing laws. Water is diverted or pumped by individuals and many public districts and, therefore, pricing is not subject to state or federal intervention. Since existing federal reclamation contracts have fixed the price of water, any increase could be effected only when those contracts come up for renewal or for future projects.

The California Aqueduct conveys contracted for quantities of water

In the case of urban water demands, the evidence is mixed but there are examples where a switch from flat rates to metered rates has resulted in decisive and permanent reductions in water use. This follows the usual expectation that an increase in price results in a decrease in demand, and the greater the price increase the greater change in demand. Behavioral patterns are oftentimes affected, which results in conservation practices including reductions in wastage from overirrigation, lawn watering, and leaky plumbing fixtures. The duration of these practices will depend, in part, upon the costs of water relative to personal income and other expenditures. This applies to industry as well, but as long as the price of water is sufficiently high to be a concern, a reduction in water demand could be expected.

A significant question involved in increasing municipal water rates is who is affected and what may be the results. Most probably the low income group would be most seriously affected, as the more affluent families would be able to more easily absorb a cost increase. Environmental amenities such as lawns, trees, fountains, and parks would likely be reduced. The U. S. Forest Service has found that well-watered trees can reduce air temperatures on a hot, dry day as much as five degrees. They also found that a single city tree provides a cooling effect equivalent to five average-sized room air conditioners running about 20 hours per day.

In summary there is a relationship between water price and demand. From a practical standpoint the ability of federal and state pricing policies would have limited effect. The tradeoffs of local environmental amenities, economic and social well-being vis-a-vis the environmental benefits of leaving more natural stream flow or some streams undeveloped require thoughtful consideration.

Water Use Efficiency and Its Effect on Demand

A great deal of attention is currently being directed toward improvements in the efficiency of use of resources as a means of decreasing expanding demands and stretching available supplies. Possibilities for more efficient use of water, range from flush toilets that use less water to desert type landscaping or applying irrigation by controlled dripping at each tree. These and various other methods can reduce the amount of water used in homes and industry, and to irrigate crops. The degree to which they would reduce the overall requirement for water supplies, however, depends on several factors.

In evaluating the effects of improving the methods of using water, consideration must also be given to the

Small sprinklers provide for efficient use of water

disposal of waste water. Where the waste water is discharged to saline water, any reduction in the amount of water originally applied will provide an equivalent reduction in demand for developed water supplies. It will also reduce the size of the waste treatment facilities. This case generally applies to coastal urban areas but only to a very limited degree to agriculture. The principal areas where agricultural returns mix with brackish water are in the Coachella and Imperial Valleys which drain to the Salton Sea.

Throughout practically all other irrigated areas and at inland urban locations, almost all excess irrigation water or urban waste water becomes part of the supply for downstream users. Any reduction in the amount of applied water will result in approximately the same reduction in return flow and therefore require a comparable amount of water from an alternative source for downstream users. With the exception of some savings in unavoidable losses, there will not be any overall savings in total water demand by improving the efficiency of application or use of water in such cases. There will, however, be other advantages and some disadvantages.

If less water is used, the costs of handling it, in particular energy for pumping, will be less. With less applied water there will generally be less leaching from irrigation, and the quantity of dissolved salts which need to be removed from the area will be less. The concentration of salts in the return flows, however, will be greater due to the reduced volume of water. Reduction in the waste water from urban areas will involve higher concentrations of salts unless there are also changes in the home and industrial practices which reduce the quantity of waste minerals.

Reduction in the amount of irrigation runoff from fields will be adverse to trees, brush, and native grasses, and the wildlife which depends on this vegetation. In most cases, and particularly the flat Central Valley, there would be scenic detriments from the loss of vegetation.

While the overall water savings from more efficient use probably will be relatively small in comparison to total usage, the advantages warrant thorough study. As water supplies become increasingly scarce improved use methods become more important.

Economic Efficiency as a Basis for Water Management

As California's supplies of undeveloped water have decreased, suggestions have been made that certain presently developed supplies could be diverted from uses having low economic returns to uses with higher economic returns. Generally this would involve a shift from agricultural production to industrial use, as well as a change in geographic location. It also suggests the shifting of water from one crop to another that might use less water and produce more economic return. Advocates of this view point out that there would be greater employment and wealth for a given quantity of water and there would not be need for as much, if any, additional water development. This concept also includes the purchase or shifting of water during periods of drought from one use such as irrigation of an annual crop to a use of greater significance to the State's economy. Such a concept has great ramifications and raises major policy issues. State law does not provide for administrative reassignment of water supplies being beneficially used.

A change in use would involve water rights as well as financial considerations. A major factor in buying out the water supply of an agricultural area is the relocation and social impact and change of life style on the people of the area. Payment for water and land values will not necessarily provide for relocation and/or gainful employment elsewhere, although some agricultural workers may retrain for industrial work if it is in the same general area. There may be increased costs in social welfare programs. It would be necessary to reimburse owners more than market values to obtain comparable relocated conditions and to assist in relocation.

Three generations have passed since the City of Los Angeles purchased the lands and acquired the water rights in the Owens Valley. The transfer of water from irrigation use to urban use was made and one of the world's major cities developed. This experience has shown, however, that long lasting social problems remain even though there was an increase in economic efficiency.

Supplemental Water Through Waste Water Reclamation

Waste water reclamation is generally acclaimed as the primary alternative to further surface water development for meeting California's future water needs. This alternative, while probably the major potential supplement to surface water development, must also be viewed from the perspective of some limitations. The following discussion outlines some key considerations, such as dissolved mineral levels, health concerns, costs, and institutional conflicts, which strongly affect policy decisions by local agencies in pursing waste water reclamation.

Waste water reclamation, as considered in this bulletin, is the planned renovation of waste water with the intent of producing usable water for a specific beneficial purpose. Biological treatment and/or demineralization may be involved.

It is important to distinguish between reclamation which results in improvement of the existing supply and reclamation which actually results in creation of a "new" supply. Both facets are important, but the creation of a "new" supply as supplemental water is the thrust of this policy issue.

Only when waste water would otherwise be discharged to saline water—or when water has been so degraded that it cannot be discharged to fresh water—does reclamation create a water supply which can be considered "new". Much of the water used in California is returned to the freshwater cycle, either directly after its use or following treatment. This includes 90 percent of the irrigation return water from nearly 9 million acres of irrigated land and the treated wastes from inland cities, particularly in the Central Valley. Although reclamation of this water would tend to enhance water quality, it would not create a new supply.

There are two main sources of water which can be reclaimed for new supplies. These are (1) the brackish agricultural drainage water which must be removed from the Central Valley and in particular the San Joaquin Valley, and (2) the urban wastes from coastal areas which are discharged to the ocean and its estuaries: It is anticipated that much of the agricultural drainage could be reclaimed for power plant cooling. The role for reclaimed coastal urban wastes is not, however, as apparent.

To undertake waste water reclamation there needs to be a supply of fresh water of good quality to begin with. Not all of this fresh water supply can be reclaimed, however. Up to 50 percent of an urban supply is used consumptively or incidentally lost. Another 20–30 percent of the initial supply is needed to carry off concentrated waste and prevent accumulation of salts in gardens, parks, etc. Accordingly, only 20–30 percent of the original supply may be available for possible reclamation.

The mineral quality of the initial supply is important in evaluating reclamation. A single cycle of water use in an urban area normally adds about 300 milligrams of salts per liter of water. The recommended limit for salts in municipal supplies is 500 milligrams per liter (mg/l) but up to 1,000 mg/l is acceptable. A large share of the urban water supply in the coastal area of Southern California is from the Colorado River and has a salt content of around 750 mg/l. A single use would cause the salt to exceed the acceptable limit, and reclaimed water would require blending with less saline water. With an increasingly greater share of water from the State Water Project used in Southern California, the widespread mineral limitation on waste water reclamation would be reduced. At the other end of the scale, the Sierra Nevada water supplies delivered to the San Francisco Bay area through the Hetch Hetchy and Mokelumne Aqueducts are of excellent mineral quality with generally less than 100 mg/l. Water delivered by the State Water Project would average less than 220 mg/l.

At this time there are significant health concerns which greatly limit urban use of reclaimed water. Development and use of a wide range of organic compounds for industrial, agricultural, and household uses, which find their way into public water supplies, are causing concern regarding effects on public health. Many of the complex compounds are stable, that is, they do not break down into simpler forms, and persist for a long time. The long-term effect of ingesting even minute amounts of some stable organic compounds is unknown and, therefore, efforts are made to avoid use of water containing the compounds. Similar concerns exist regarding viruses which may not be fully eliminated in waste water treatment and reclamation processes.

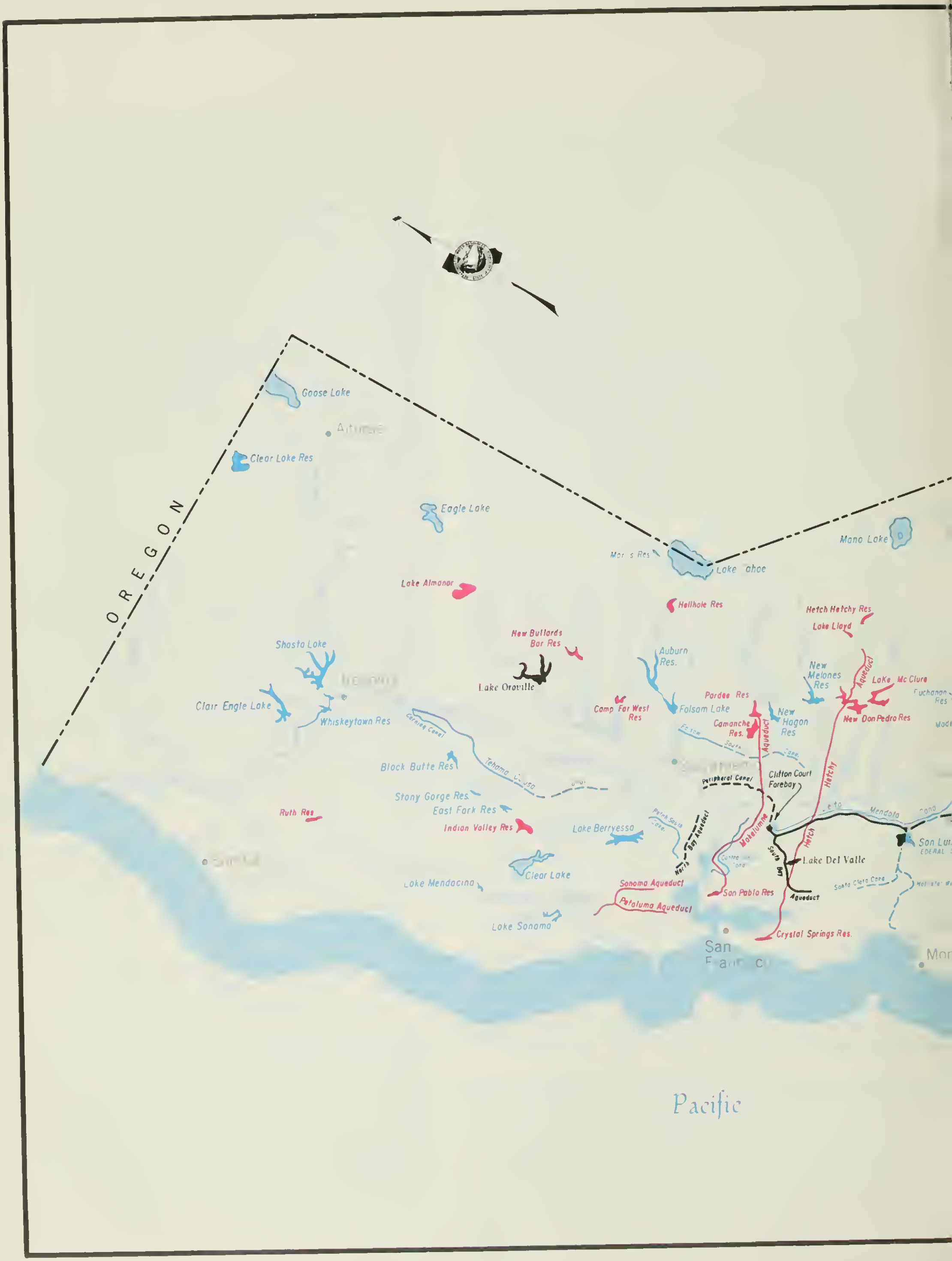
Concern about viruses has caused health officials to reject direct distribution and use of reclaimed water for human consumption. Concern regarding effects of stable organic compounds has caused health officials to greatly restrict the use of reclaimed water for ground water recharge where the ground water basin is a source of water for human consumption. Since ground water moves very slowly and does not mix very well, reclaimed water would generally move as a unit away from the point of recharge and could remain in the basin for many years.

Until the uncertainties regarding health are resolved, plans for using reclaimed water are being directed toward nonpotable uses such as irrigation and industrial, especially power plant cooling. Efforts are being launched by local and state agencies to develop research programs on these health concerns. The Department of Water Resources, in cooperation with the State Water Resources Control Board with help from the University of California, is initiating work leading to specific and coordinated studies of the stable organic and virus problems.

General industrial use of reclaimed water would require separate distribution systems and in-plant modifications. The costs are generally not competitive with fresh water, although as the requirements for treatment of waste water increase, industry will find it more advantageous to recirculate its water. Thermal electric power plant cooling could be a major use of reclaimed water, but the plants cannot usually be located near urban centers for environmental and safety reasons. Consequently, the reclaimed water from urban areas would need to be conveyed long distances with considerable expense and use of energy.

In addition to the costs directly associated with reclamation, consideration must be given to costs already invested in facility capacity for future needs. These sunk costs are frequently quite great since many water projects and distribution systems are constructed with capacity for the future to take advantage of economies of scale. Economic evaluation of waste water reclamation must take into account the sunk costs in existing facilities.

Generally separate local agencies have been organized to handle water supply and waste. Full consideration of the reclamation of waste water may be inhibited due to institutional constraints. The appropriate agencies to pursue this potential is one of the policy issues needing attention.



OREGON
Goose Lake
Clear Lake Res
Eagle Lake
Mono Lake
Lake Almanor
Hellhole Res
Hetch Hetchy Res
Lake Lloyd
New Bullards Bar Res
Lake Oroville
Shasta Lake
Clair Engle Lake
Whiskeytown Res
Corning Canal
Auburn Res.
Pardee Res
Camp Far West Res
Folsom Lake
Camanche Res.
New Melones Res
New Hogan Res
Lake Mc Clure
New Don Pedro Res
Aqueduct
Hetch Hetchy
Mokelumne Aqueduct
Block Butte Res
Stony Gorge Res.
East Fork Res
Indian Valley Res
Ruth Res
Lake Berryesso
Peripheral Canal
Clifton Court Forebay
North Bay Aqueduct
South Bay Aqueduct
Lake Del Valle
Mendota
Clear Lake
Lake Mendocino
Sonoma Aqueduct
Petaluma Aqueduct
San Pablo Res
Crystal Springs Res.
Lake Sonoma
San
Pacific

Legend

LOCAL DEVELOPMENT
STATE WATER PROJECT
FEDERAL DEVELOPMENT

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III. ALTERNATIVE FUTURES FOR CALIFORNIA

As briefly mentioned in the Introduction, in this Bulletin the Department of Water Resources has departed from the usual practice of presenting the future only as an extension of past trends. Although trend analysis is a valid method of forecasting future happenings, a projection based on past events will not necessarily describe the most probable future level of development. Accordingly, in presenting a number of possible future levels, the Department recognizes that a variety of outcomes are possible and that chance or policy decisions will produce changes that are not mere projections of past events.

Because of the rapid changes occurring in society, including its outlook and values, planning on the basis of alternative futures is extremely relevant today. The Department of Water Resources recognizes that several futures are equally possible, and that they can be influenced by deliberate activity. On the other hand, identification and evaluation of alternative futures, and the consequences of alternative choices are not intended as a recommendation for a particular course of action. Rather, the analyses are intended to provide information for public review and for those who must decide on policy.

The importance of evaluating a range of water management and demand alternatives is evidenced by the uncertainty involved in projections of the location, size, and timing of future water demands and other water management needs. Five recent factors that have contributed to this uncertainty are (1) the recent downward trend in birth rates, (2) the opening of the Chinese and Russian agricultural markets, (3) new, stricter air and water quality standards, (4) future land use policies, and (5) the impact of recent environmental preservation and enhancement trends.

The alternative future levels of population, agriculture, and energy discussed in this chapter were derived from various combinations of possible future California conditions. They may be used to describe the future, 20, 30, or 50 years from now and to indicate the direction and size of changes in water and land use that might result from changes in public policy, technology, and other factors. They are also the bases for the alternative levels of future water demands presented in Chapter IV. Because data on the outlook for fish, wildlife, and recreation are limited, only one projection was made for these needs. The Department of Water Resources is also concerned with other water-related needs that must be included in the planning of water resources projects. These include such factors as environmental quality, water quality, and flood control. Whereas the needs for such benefits are evident, they cannot be readily expressed as numerical demands for water.

Population

Growth has been the trend in California's population during all of the more than 150 years that records have been kept. The rate of growth has varied during different periods in the last half century, but in all that time, it has far exceeded the growth rate for the entire United States. Table 1 summarizes population growth rates in California and the United States by decades since 1920.

Table 1. California and U.S. Population and Percent Increase by Decades, 1920–1974

Year	Decade	California population: Millions	California population: Percent increase	U.S. population: Millions	U.S. population: Percent increase
1920	--	3.4	--	107	--
	1920–30	--	68	--	16
1930	--	5.7	--	123	--
	1930–40	--	21	--	8
1940	--	6.9	--	132	--
	1940–50	--	54	--	15
1950	--	10.6	--	152	--
	1950–60	--	50	--	19
1960	--	15.9	--	180	--
	1960–70	--	26	--	14
1970	--	20.0	--	205	--
1972	--	20.5	--	209	--
1974	--	20.9	--	212	--

Births and Migration

The trends, influences, and driving forces that affect population growth are now changing in the United States and particularly in California. Although the number of potential mothers is higher than ever before, fewer babies were born in the U. S. last year than in any year since 1945. In both California and the nation, the birth rate has decreased to an annual rate equivalent to 1.9 births per woman of child-bearing age. A replacement level, often referred to as "zero population growth," is 2.11 children per woman. The peak year for births in the U. S. was 1957, when the birthrate was equivalent to 3.35 births per woman of child-bearing age.

Another very important factor influencing California's population growth is net in-migration—those entering the State and establishing residency minus those leaving the State. For many years, net in-migration exceeded 300,000 annually with a high of 357,000 in 1963. Then, in the late 1960s and early 1970s a drop occurred with a low of about 16,000 in 1970. However, there has since been a steady increase; in 1973 a net in-migration of 84,000 was experienced.

Future Population Levels

Four population projections, based on the factors in Table 2, are used in this report. The letter designators (C, D, and E) are those used by the U. S. Bureau of the Census and the State Department of Finance to designate population series based on fertility rates, that is, the average number of children born per woman of child-bearing age. The numbers represent annual net migration into California.

Table 2. Population Factors

Alternative projection	Population series	Fertility rate	Net migration
I	C	2.8	150,000
II	D	2.5	150,000
III	D	2.5	100,000
IV	E	2.1	0

Table 3 presents four projections of future California population for 1980 through 2020. Continued population growth results under each of the four sets of assumptions. However, the projected growth under each of the four is lower than that experienced in California during any decade since 1920. Although E–O is often referred to as zero growth, the population still would increase and is not expected to stabilize until after 2020. The historic growth of California's population from 1920 through 1973 and the four alternative projections of future growth are shown in Figure 4.

Table 3. Projected California Population (in millions)

Alternative projections	Year				
	1980	1990	2000	2010	2020
I (C-150)	23.0	27.4	31.9	37.2	43.3
II (D-150)	22.8	26.7	30.5	34.6	39.1
III (D-100)	22.7	26.1	29.3	32.8	36.6
IV (E-0)	21.9	23.6	24.7	25.7	26.5

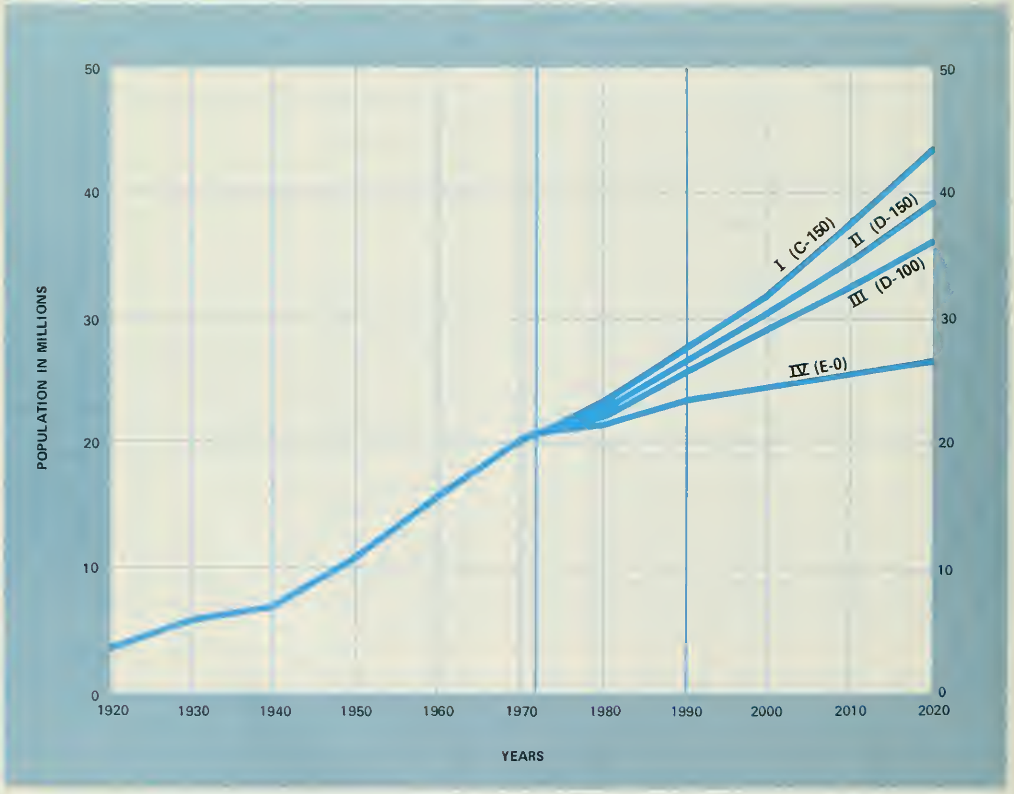


Figure 4. California Historical and Projected Population Growth

Using the statewide projections as a base, the State Department of Finance has also produced county-by-county population projections, which take into account different fertility patterns for different counties and expected different future levels of net migration by county. On the basis of these county-by-county projections, the Department of Water Resources has produced four alternative future population levels, designated I through IV, for each of the hydrologic study areas of the State, as shown in Table 4.

Table 4. Population in California—1972, 1990 and 2020
(in thousands)

		Alternative future projection							
		I (Series C-150)		II (Series D-150)		III (Series D-100)		IV (Series E-0)	
Hydrologic study area	1972	1990	2020	1990	2020	1990	2020	1990	2020
North Coastal	180	250	390	240	350	230	310	210	230
San Francisco Bay	4,630	5,940	8,670	5,800	7,920	5,680	7,350	5,270	5,700
Central Coastal	840	1,370	2,430	1,340	2,200	1,290	2,030	1,130	1,370
South Coastal	11,240	14,620	22,510	14,260	20,300	13,930	19,140	12,510	13,790
Sacramento Basin	1,210	1,700	2,600	1,670	2,400	1,630	2,230	1,470	1,620
Delta Central Sierra	470	760	1,730	730	1,550	710	1,420	640	930
San Joaquin Basin	440	650	1,140	640	1,010	620	940	560	660
Tulare Basin	980	1,280	2,030	1,250	1,820	1,240	1,730	1,160	1,360
North Lahontan	40	70	110	70	100	70	90	60	60
South Lahontan	240	410	1,040	370	870	370	820	290	380
Colorado Desert	230	350	650	330	580	330	540	300	400
Totals	20,500	27,400	43,300	26,700	39,100	26,100	36,600	23,600	26,500

Agriculture

Production of food and fiber in California is by far the most significant single enterprise affecting use of the State's land and water resources. Eighty-five percent of all present water use in the State is by irrigated agriculture. Whereas the demand for food and fiber is primarily a function of the number of people in the United States and their eating habits, California agriculture is also affected by the foreign market and our competitive position with other producers.

A number of social and economic trends and events during the past decade have caused a major change in the world food situation. Since the publication of Bulletin 160-70 in December 1970, an era of commercial food surpluses has been superseded by a worldwide shortage of food and fiber. Global food reserves are at an all-time low, primarily because of widespread droughts in various parts of the world. Also responsible are population growth and a rising affluence, particularly overseas, which is evidenced by a growing demand for meats, specialty foods, vegetables and fruits, and a decreasing demand for food grains, beans, and other starchy foods.

A singular combination of climate, large areas of fertile land, and available water resources enable California's farmers to produce considerably more food and fiber than can be consumed locally. As a result, other areas of the nation and the world look to California to satisfy many of their supplemental needs for food products. National and foreign markets are therefore significant considerations in studies of both possible future demand for California crops and future water requirements.

Five Governing Factors

Four alternative levels of future agricultural production in California were developed from alternative assumptions regarding the following five factors:

- National population.
- Per capita consumption of food.
- Foreign trade.
- California's share of national production.
- Per acre yields of California crops.

The significance of each of these factors is presented in the following paragraphs:

a. *National population* growth will be one of the principal determinants of the State's agricultural future, because of the large quantities of California produce marketed in other states. Along with the expanding national population, a growing affluence has created increased demands for many of California's specialty crops as well as for its more staple food and fiber crops. Total national consumption food and fiber is computed as a function of national population and per capita consumption.

b. *Per capita consumption* is the quantitative measure of the various kinds of food and fiber consumed per person. Studies of eating habits show that tastes for various foods change with rising incomes and with changes in living and working patterns. As personal income increases, the *quantity* of food consumed does not necessarily increase, but the *types* of food consumed generally change noticeably. In general, families with higher incomes tend to eat more meat, fruit, vegetables, and dairy products, whereas families with lower incomes consumer more starchy, less-expensive foods such as bread, potatoes, beans, and rice.

c. *Foreign Trade.* Recent developments in international agricultural trade have revealed several profound changes, including an apparent revolution in world dietary patterns and major changes in agricultural trade flows and trade policies. Per capita incomes around the world are growing and will probably continue to grow. As incomes rise, more people are able to improve their life styles, with greater security and individual well-being. Among the first areas of improvement are upgraded diets. This trend, coupled with increasing population, not only increases total food consumption, but also creates a demand for a wider variety of foods.

As the nations of the world use more agricultural commodities, they buy more in the world market and particularly from the United States. Over the past 10 years, American agriculture has conducted an aggressive advertising campaign, which has enabled the United States to sell a greater quantity of produce in the international market. A review of U. S. agricultural exports since 1960 shows that California's share has grown to 54 percent of foreign sales of fruit, 27 percent of the vegetables, 22 percent of the rice, 11 percent of the cotton, and 94 percent of the nuts.

d. *California's share of national production.* The California agricultural industry has demonstrated considerable success in competing for greater shares of U. S. production. This trend is expected to continue, although opportunities for increasing shares will differ considerably among specific crops.

Irrigated corn field in California

e. *Crop yields.* The quantity of produce per acre is an important factor in forecasting California's ability to satisfy future demands for food and fiber. Over the years, crop yields have been increased by such innovations as new machinery, hybrid seeds, use of fertilizers, herbicides, and pesticides, higher plant populations per acre, and improved managerial skills. Further research and improved technology should continue to enhance the productivity of California agriculture.

On the other hand, the effects of the energy crisis and certain environmental constraints could result in smaller increases in crop yields. If, for example, the recent scarcity of petroleum continues, it could result in shortages of fertilizers, pesticides, and other petroleum-based products that are essential to present crop yields and production. Concern over the environmental effects of certain fertilizers and some of the more effective pesticides and herbicides could result in constraints on their use.

Future Agricultural Levels

To project alternative levels of future agricultural production in California, the five factors described in the preceding paragraphs were analyzed, and one or more values for each were selected. Four combinations of these values resulted in four alternative levels of future crop acreage. In all four cases, the same values were used for *per capita consumption* and *California's share of the national market.* These were combined with two values for *national population, net foreign trade*, and *average crop yields* as shown in Table 5, which also presents four alternative future levels for California agriculture expressed as irrigated crop acreage required in 1990 and 2020. These projections of crop acreage were modified to account for (1) lands planted but not harvested, and (2) the estimated future acreage of dry-farmed crops and double-cropping, to determine the four alternative projections of irrigated land shown in Figure 5.

Table 5. Alternative Future Levels for California Agriculture

Alternative	National population		Net foreign trade		Crop yields		Irrigated crop acreage required (1,000s of acres)	
	Series D	Series E	High	Low	1968	Modified	1990	2020
I	X		X			X	10,600	12,100
II	X			X		X	10,200	11,200
III	X			X	X		9,700	10,300
IV		X		X		X	9,500	9,800

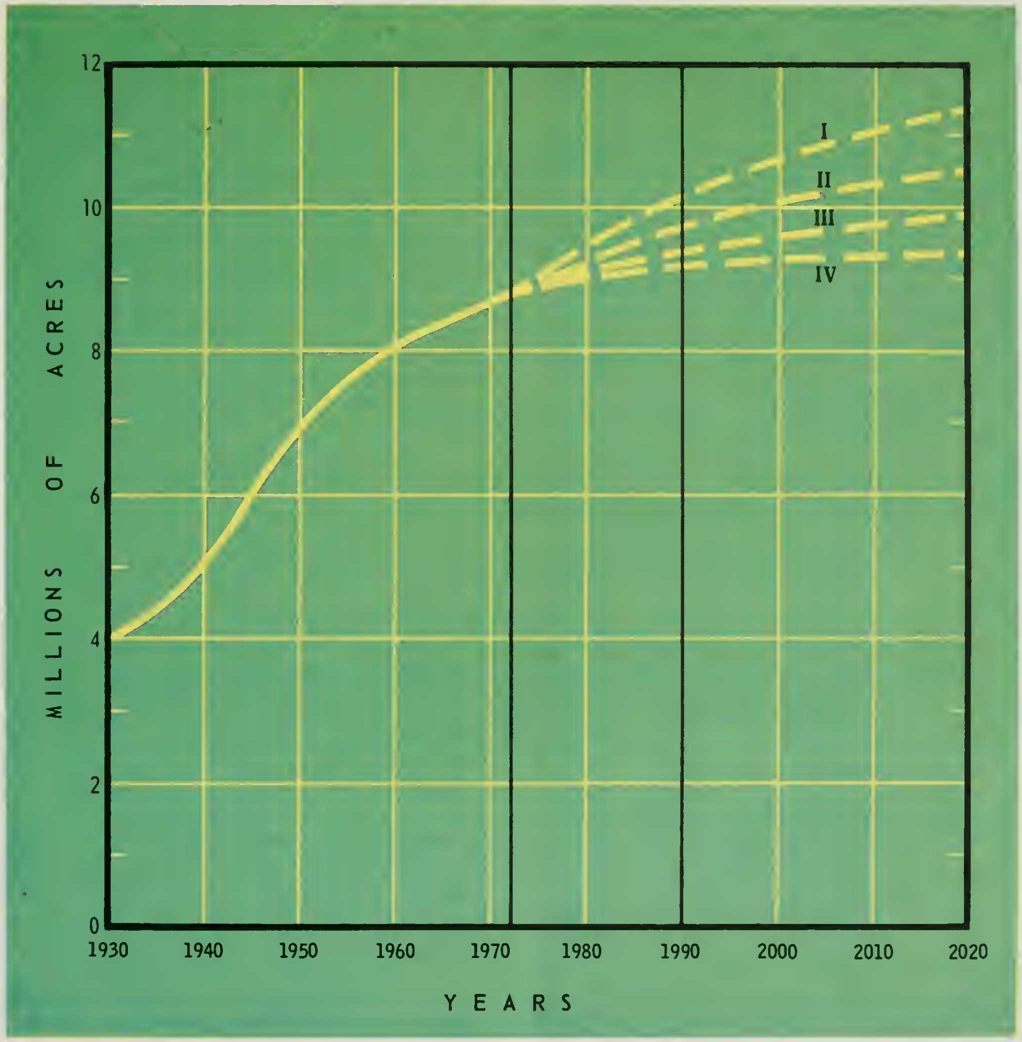


Figure 5. Historic and Projected Irrigated Land Area

Energy

The future location of thermal electrical power plants will affect the future requirements for fresh cooling water in California. At the present time, most California thermal plants are located along the Pacific Coast, where ample sea water is available for cooling. However, because of recent restrictions on the construction of thermal plants along the coast, the need to locate future plants at inland sites will create large new demands for fresh cooling water.

Trends and Influences

Until recently, energy has generally been taken for granted in California. During the last two years, however, the energy "crisis" has caused uncertainty about the future, and concerned individuals and groups are reexamining former assumptions about the future of energy capacity and demands. Factors that affect the future consumption of electrical energy are as follows:

1. Factors which cause a continued increase in electricity consumption:

   a. Population growth
   b. Extension of existing uses of electricity
      (1) Resistance heating
      (2) Refrigeration cooling
      (3) Transportation—trains, mass transit
   c. New uses for electricity
      (1) Transportation—autos
      (2) Conversion to alternative forms of energy
      (3) Desalting

2. Factors which would contribute to a lower rate of increase in electricity consumption:

   a. Decline in birthrate and net in-migration
   b. Rising energy costs
   c. More efficient use of energy
      (1) Conservation measures to reduce waste
      (2) Better appliances
      (3) Beneficial uses of waste heat
   d. Substitution of alternative forms of energy.

Most of the factors that tend to increase energy consumption have prevailed in California since 1945. In the future, however, the factors that tend to reduce energy consumption are expected to dominate, For example, population growth is slowing down, and per capita energy use, which increased rapidly between 1940 and 1972, is also slowing down. In addition, the cost of energy is increasing significantly and will probably continue to increase. Projection of certain other factors is more uncertain. For example, the impact of alternative forms of energy, such as solar energy, is still highly speculative.

Two Future Energy Levels

To develop future projections of electrical energy demand and capacity, the Department of Water Resources has used (1) values shown in a 1972 report by the Rand Corporation [1] which presents detailed analyses of five different cases, and (2) a 1973 report by the California Resources Agency,[2] which presents future projections made by the California Public Utilities Commission. The reports forecast future demands for electrical energy through 2000 and 1991 respectively; for the estimates presented in Table 6 the Department has projected the values to 2020.

Thus, the low projection shown in Table 6 uses values from the low growth case in the Rand report. The values beyond 2000 were estimated on the basis of a 3 percent compound annual growth in electrical energy use. The high projection was obtained by using the projection in the Resources Agency report, which was also projected to 2020. The projections of future generation of electrical energy were computed from the estimated demand values.

Table 6. Projected Requirements for Electrical Energy (billion kilowatt hours per year)

Year	Electrical energy sales		Electric energy generation[c]	
	High estimate	Low estimate	High estimate	Low estimate
1972	140	140	155	155
1990	420	247	466	274
2020	1600[a]	600[b]	1780	670

[a] Estimated by projecting 4.4 percent rate of growth from 2000.
[b] Estimated by projecting 3.0 percent rate of growth from 2000.
[c] Electric energy generation differs from sales by 10 percent losses.

Figure 6 shows historic consumption of electrical energy from 1950 through 1972 and the high and low estimates of future energy use in California.

Thermal Power Plant Siting

The technology of electrical energy production is changing rapidly, and by 2020, new methods of production, e.g., fusion, gas turbines, which would reduce the need for cooling water, may have been developed. However, over the next 50 years, and despite the significant remaining hydroelectric energy potential in California [3], most of the additional electrical energy generated in California is expected to be developed by thermal power plants fueled by nuclear energy, which

[1] The Rand Corporation, "California's Electricity Quandary, I. Estimating Future Demand." September 1972.
[2] State of California, The Resources Agency, "Energy Dilemma, California's 20-year Power Plant Siting Plan." June 1973.
[3] Department of Water Resources Bulletin No. 194, "Hydroelectric Power Potential in California", March 1974.

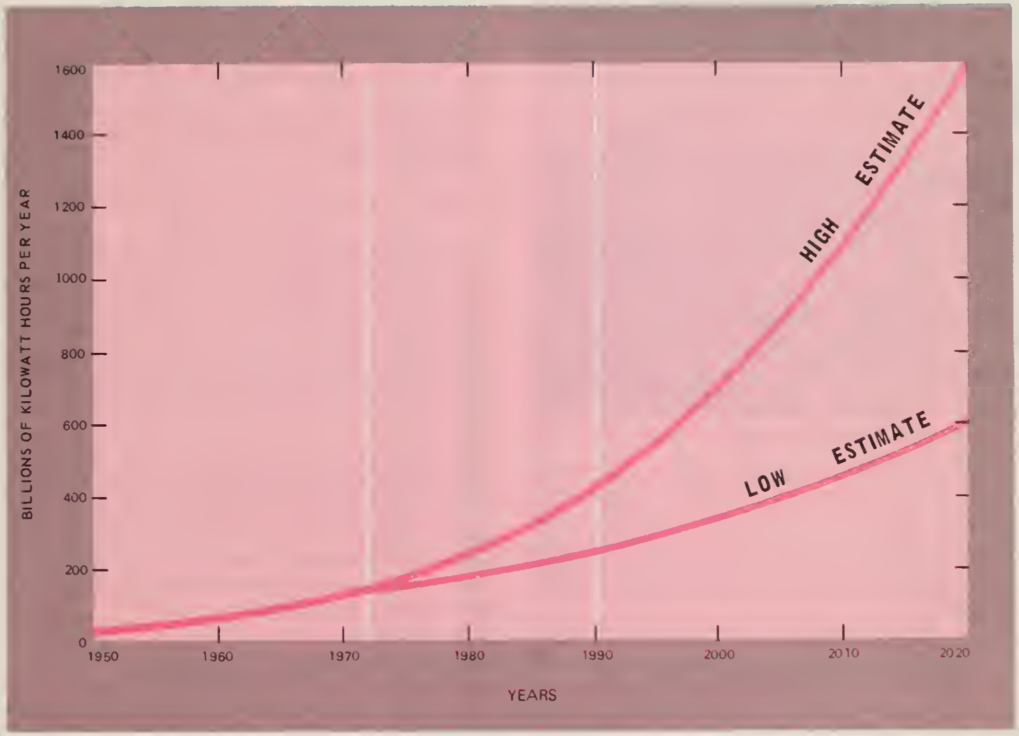


Figure 6. Historic and Projected Electrical Energy Requirements

require substantial quantities of cooling water for operation. Accordingly, projections of future thermal power generation and the location of thermal plants are important factors in the determination of California's future water requirements.

About 90 percent of California's existing major thermal power plants have been constructed along the coast. However, because of the public desire to preserve the esthetic appearance of the coastline, the possible impact of heated-water discharges on the marine environment, and the potential earthquake hazard along the coast, most future thermal plants will probably be constructed at inland locations.

Analyses of power plant siting criteria based on seismisity and population, as shown in the 1973 Energy Dilemma Report by the California Resources Agency, indicate that the most favorable inland areas are in the Central Valley and the eastern portion of the Colorado Desert. These analyses were not in sufficient detail to determine whether other localized parts of the State would not also be suitable as sites for thermal plants.

In view of the uncertainties about power plant siting, two alternative locations for thermal plants were considered. An assumption was made for this report that either one-third or two-thirds of future thermal generating plants would require closed-cycle evaporative cooling, which would have to be supplied from inland sources of fresh water. The remaining thermal plants would be located on the coast and use sea water for cooling.

Most California thermal power plants are along the ocean

These two assumptions regarding future plant location were combined with the two levels of electrical energy generation shown in Table 6 to derive four alternative futures for thermal power plants in California. Installed capacities of electric generating plants requiring inland sources of cooling water are presented in Table 7.

Table 7. Additional Inland Thermal Power Generation (in billion kilowatt hours)

Alternative future	Energy demand	Fresh water cooling[a]	Generation requiring cooling	
			1990	2020
I	High	2/3	158	790
II	High	1/3	88	420
III	Low	2/3	52	250
IV	Low	1/3	44	150

[a] Fraction shown indicates that portion of additional thermal generation using fresh water for cooling purposes. The remaining portion of cooling need would be met by ocean water.

Other Water Resources Management Needs

Population, agriculture, and energy, as discussed in the preceding paragraphs, are expressed in terms of alternative future demands for urban, agricultural, and power plant cooling water in Chapter IV. However, other water-related needs must be included in planning for water-resources management. These needs include (1) recreation, fish, and wildlife, (2) environmental quality, (3) water quality, and (4) flood control.

The discussion of water demands in Chapter IV includes a single projection for water for recreation, fish, and wildlife. Environmental quality, water quality needs, and flood control are discussed in Chapter IV in terms of environmental benefits or values. The trends and influences affecting these factors are discussed in some detail in the full report.

IV. DEMANDS FOR WATER

The future water demands presented in this chapter are discussed on three different bases:

1. Demands for (a) urban uses, (b) irrigated agriculture, and (c) power plant cooling are presented in terms of alternative future development.

2. Demands for recreation, fish, and wildlife are presented as a single projection only.

3. Other demands, such as those for environmental enhancement, water quality protection, flood control, and navigation, are not discussed in quantitative terms but must be considered in water resources planning.

Urban Demands

Urban water uses include residential (68 percent); industrial (18 percent); commercial (10 percent); and governmental (4 percent). For the determination of future water demands, these four broad categories were combined, and the urban demands presented in Table 8 were derived as the product of alternative projections of population (Table 2) and per capita or unit water use values.

Per capita use is determined by dividing total urban water use in a given area by the population of that area. Per capita use varies considerably from city to city and region to region. Factors affecting per capita use include climate, personal income and life style, family size, type of community, level of industrialization, metering, and system losses.

Climate has the most significant effect on per capita use, particularly residential use. In warm, arid, and heavily populated regions, for example, large quantities of water are used for lawn and garden irrigation. In such areas, summer use exceeds winter used by several hundred percent. On the other hand, as population density increases, especially as condominium and high-rise apartment dwellers increase, lawn and garden areas tend to decrease, thus reducing total per capital use.

Industrial water use is also affected by a number of variables, principally by the type of industry.

Alternative projected urban water demands are presented in Table 8 for each of the State's hydrologic areas and as statewide totals. The demands are expressed in terms of *applied* water, which is the total quantity of water that must be delivered to each point of use, e.g., the house, factory, etc., plus local system losses.

Table 8. 1972 and Projected Urban Applied Water Demand
(1,000 acre-feet)

	North Coastal	San Francisco Bay	Central Coastal	South Coastal	Sacramento Basin	Delta-Central Sierra	San Joaquin Basin	Tulare Basin	North Lahontan	South Lahontan	Colorado Desert	Total
1972	93	990	181	2,370	470	173	192	363	23	89	99	5,040
Alternative I												
1990	104	1,480	308	3,130	700	251	295	493	40	154	148	7,100
2020	126	2,240	569	4,830	1,040	537	548	798	68	387	275	11,400
Alternative II												
1990	102	1,460	300	3,050	687	247	287	479	40	139	142	6,930
2020	120	2,070	516	4,360	968	490	485	718	59	326	246	10,400
Alternative III												
1990	101	1,430	289	2,980	674	239	279	471	39	136	139	6,770
2020	114	1,940	473	4,120	908	451	451	679	54	306	230	9,730
Alternative IV												
1990	97	1,340	252	2,670	621	219	249	441	32	108	126	6,160
2020	100	1,570	318	2,980	702	323	307	530	35	143	173	7,170

Agricultural Demands

In 1972, about 8.75 million acres in California were under irrigation. Statewide applied water demands for irrigation in 1972 were 31.7 million acre-feet. The alternative projected water demands shown in Table 9 were derived as the products of estimated future crop acreage (Table 4) and appropriate unit values of applied water.

Unit values of applied water are determined on the basis of (1) data on current irrigation practices for each crop, and (2) expected changes in irrigation management and techniques. The irrigation system used—sprinkler, wild flooding, furrow, etc.— is dependent on factors unique to each farm operation. In 1972, about 2 percent of California crop lands were irrigated by wild flooding, i.e., water flowing down slope from a network of distribution ditches, 17 per-

Table 9. 1972 and Projected Agricultural Applied Water Demand
(1,000 acre-feet)

	North Coastal	San Francisco Bay	Central Coastal	South Coastal	Sacramento Basin	Delta-Central Sierra	San Joaquin Basin	Tulare Basin	North Lahontan	South Lahontan	Colorado Desert	Total
1972	710	250	1,030	920	6,020	2,470	5,450	10,890	420	310	3,220	31,700
Alternative I												
1990	720	290	1,240	730	7,940	3,220	6,620	13,070	430	300	3,320	37,900
2020	740	330	1,310	530	9,080	3,700	7,320	14,870	430	250	3,320	41,900
Alternative II												
1990	720	280	1,200	720	7,540	3,010	6,390	12,510	430	300	3,320	36,400
2020	740	320	1,270	510	8,350	3,540	6,600	13,720	430	250	3,320	39,000
Alternative III												
1990	710	290	1,190	720	7,050	2,810	6,040	11,750	430	300	3,320	34,600
2020	730	310	1,240	520	7,540	3,250	6,180	12,360	430	250	3,320	36,100
Alternative IV												
1990	710	280	1,200	750	6,960	2,710	5,750	11,580	400	300	3,320	34,000
2020	730	280	1,220	520	7,410	3,020	5,750	11,750	400	250	3,320	34,600

cent were irrigated by sprinkler, and most of the remainder were irrigated by border, basin, or furrow systems. The efficiency of sprinkler systems, in terms of both water used and labor requirements, is generally greater than that of other irrigation methods. Because water supplies are limited or costly in some areas, and labor and other operating costs are continuously rising, the use of sprinklers is expected to increase. A new irrigation method, drip irrigation, which has the potential for even greater efficiency of water application, is being studied with great interest.

Alternative projected agricultural applied water demands are shown in Table 9 for each of the State's hydrologic area and as statewide totals.

Power Plant Cooling Water

The calculation of future applied water demands for thermal power plant cooling was complicated by uncertainties regarding (1) the total capacities and types of future plants, and (2) the location, i.e., coastal or inland, of future thermal plants that require cooling water. As shown in Table 6, high and low projections of future energy sales and capacity have been forecast for California. The siting question is also significant because (1) for power plants located along the coast, sea water is readily available for once-through cooling,* but (2) inland plants will require large quantities of fresh water for cooling.

Analyses of power plant siting indicate that the most favorable inland areas for sites are in the Central Valley and the eastern portion of the Colorado Desert. Consequently, most of the future demand for cooling water was assumed to occur in those areas.

Drip irrigation of young pistachio nut tree

* Sea water is run through the plant condensers and returned to the ocean.

The calculations of projected demands for cooling water were made on the basis that, depending on the location of future thermal power plants (coastal or inland), either ⅓ or ⅔ of the future cooling-water demand would be supplied by fresh water. These two assumptions were then combined with both high and low assumptions of future generation (Table 6) to derive the four levels of alternative demands shown in Table 10.

The demands shown in Table 10 are for water from inland sources only. If part of these demands are met with reclaimed waste water, which is a potential source of cooling water, the requirement for high-quality fresh water would be reduced accordingly.

Table 10. Power Plant Fresh Water Cooling Requirements (1,000 acre-feet)

Hydrologic study area	1972	Alternative futures 1990 I	II	III	IV	2020 I	II	III	IV
South Coastal	18	30	30	30	30	80	40	0	0
Sacramento Basin	0	50	0	0	0	140	60	50	0
Delta-Central Sierra	20	100	75	50	40	150	100	110	70
San Joaquin Basin	0	0	0	0	0	140	70	0	0
Tulare Lake Basin	0	70	35	20	20	240	130	60	60
South Lahontan	0	10	10	10	0	100	50	0	0
Colorado Desert	0	130	70	40	40	250	130	130	80
State total	38	390	220	150	130	1,100	580	350	210

Recreation, Fish and Wildlife

Both California and the Federal Government regard recreation, along with protection and enhancement of fish and wildlife, as important features of water projects. The California Water Code prescribes that recreation facilities, fisheries, and wildlife habitat be given equal consideration with other purposes of proposed water projects.

In some parts of the State, especially the North Coastal Area, where the tourist trade and commercial fishing are key features of the local economy, recreation, fish, and wildlife represent the greatest local need for water. In other parts of the State, particularly the northeastern counties and the Central Valley, water is needed to restore severely depleted marshlands for waterfowl in the Pacific Flyway. Since the early 1900s, marsh habitat in the State has declined from some 3.5 million acres to 400,000 acres and is still declining.

To support recreation, fish population, and wildlife habitat, streamflow must be adequate, and water quality and temperature must be satisfactory. However, water required to maintain streamflow is not consumed and is available for other uses downstream. As a matter of fact, *consumptive use* of water for recreation, fish, and wildlife amounts to only about 2 percent of the total applied water demand in California. The following tabulation is a general summary of consumptive (out-of-stream) and nonconsumptive (instream) requirements.

Category	Type of use: Consumptive	Nonconsumptive
Recreation	Water supply, sanitation, swimming lagoons	Swimming, boating, water-skiing, general esthetics
Fish	Hatcheries, rearing ponds, processing	Stream habitat, fishing, spawning
Wildlife	Refuges and management areas, duck clubs	Marshland habitat, hunting

The consumptive uses shown in the preceding tabulation comprise the applied water demands shown in Table 11 for each of the hydrologic areas of the State:

Table 11. Applied Water Demands for Fish, Wildlife, and Nonurban Area Recreation (1,000 acre-feet)

Hydrologic study area	1972	1990	2020
North Coastal	323	359	362
San Francisco Bay	24	37	46
Central Coastal	2	3	6
South Coastal	6	19	23
Sacramento Basin	125	170	174
Delta-Central Sierra	6	7	9
San Joaquin Basin	91	94	95
Tulare Basin	43	68	70
North Lahontan	11	11	13
South Lahontan	4	16	22
Colorado Desert	20	22	26
Total	655	806	846

As explained in the preceding paragraphs, most of the water required for recreation, fish, and wildlife is for the maintenance of adequate streamflow only and is not consumed. For example, water may be released from a storage reservoir to enhance streamflow; this water is not consumed and may continue downstream to satisfy a part of other water demands. Many water-rights permits and licenses, and Federal Power Commission licenses, issued to public and private agencies provide for maintenance of streamflow and reservoir levels to protect and enhance fisheries and wildlife habitat.

Other Water Demand Considerations

Although demands for environmental enhancement, water quality control, flood control, and navigation are often significant features of water resources planning, in many cases they cannot be readily quantified as, for example, are economic demands for urban or agricultural water. Moreover, because they involve little or no consumptive use of water, they need not be identified in terms of specific quantities of water; yet, they must be included in overall project planning.

Environmental Enhancement

By their very nature, water development projects provide substantial natural environmental benefits, even though some early water projects may not have been planned and carried out with environmental enhancement as a specific purpose. On the other hand, today, natural environmental benefits are a definite part of water resources planning. A few examples of such benefits include 22 State Water Project reservoirs, which have been designated not only for water storage but also as recreational lakes—for fishing, boating, swimming, camping, and general relaxation and esthetic enjoyment. Other examples include the public fishing sites along the California Aqueduct.

Many other examples of such benefits can be cited, particularly those provided by streams used for the conveyance of water supplies and the storage reservoirs of public and private agencies in California. A number of such agencies, such as The Metropolitan Water District of Southern California, the East Bay Municipal Utilities District, Pacific Gas and Electric Company, Sacramento Municipal Utility District—to name only four—have developed public recreation areas. Such benefits are also provided at most federal water projects in California.

Passage of the California Wild and Scenic Rivers Act in 1972 maintained substantial environmental benefits. As discussed in Chapter 1, the Act designates that eight California rivers be classified as wild, scenic, and recreational, and that they must be maintained as free-flowing rivers for the enjoyment of all the people of the State and for future generations.

Water Quality Control

Closely related to the trend toward environmental enhancement is the increasing emphasis on clean water and the abatement of water pollution. The increasing use of the nation's surface water as both a source of water supply and a conveyance system for disposal of wastes has caused the Federal Government and many State governments to begin correcting existing and potential pollution problems.

Percolation ponds along Los Gatos Creek also provide recreation

At the federal level, Public Law 92-500, administered by the Environmental Protection Agency, establishes national goals and policies, sets forth comprehensive programs for water pollution control, and sets standards for enforcement. The objective of Public Law 92-500 is to restore and maintain the chemical, physical, and biological integrity of the nation's waters.

Here in California, water quality control policies and programs are established by the State Water Resources Control Board and carried out with the assistance of nine Regional Water Quality Control Boards. Basic authority for the State and Regional Boards was established by both the Water Quality Act of 1949 and the Porter-Cologne Water Quality Control Act of 1970.

The State and Regional Boards have definite responsibilities in carrying out provisions of federal Public Law 92-500, including the preparation of water quality control plans for California in 16 planning basins covering the entire State. The general objectives of these basin plans are to maintain or, in some instances, to enhance water quality in California.

Flood Control

Flood control is a water-related, although nonconsumptive, demand that must be considered in water resource management planning. The objective is to reduce flood damage in the most effective way.

A combination of structural measures, such as dams, reservoirs, and levees, and nonstructural measures, such as zoning of floodplains to prevent development in flood-prone areas, is usually the most effective method of reducing flood losses. However, structural measures, particularly dams and reservoirs, are becoming more difficult to authorize and finance. Therefore, floodplain zoning, which is carried out by local governments, may provide the primary means for reduction of losses.

For almost 40 years, the Federal Government has dominated the planning and construction of flood-control structures in major river basins, with state financial aid in California for the costs of land, easements, and rights-of-way. However, the picture is changing, and the trend today is toward more local participation in flood-control planning and, especially, in financing control measures. Legislation adopted in 1973 reduced reimbursement by the State, thus requiring local agencies to assume a significant portion of the initial costs of projects.[1]

Navigation

The only significant commercial navigation on fresh water within the State extends from the Sacramento-San Joaquin Delta upstream to the Port of Stockton via the Stockton Deep Water Channel, to the Port of Sacramento via the Sacramento River and Sacramento Deep Water Channel, and upstream on the Sacramento River to Colusa.

Most of the fresh water channels used for commercial navigation are within the zone of tidal influence so that minimum depths do not depend entirely on the rates of river flow. The exception is the reach of the Sacramento River from Sacramento to Colusa. Under the Sacramento River Shallow Draft Channel Project Act, a 145-mile channel up to 200-feet wide was excavated from Suisun Bay to Colusa. Downstream from Sacramento, the minimum depth of channel is 10 feet; upstream the minimum depth is 6 feet.

Very low river flows can result in below-minimum depths within the Sacramento River Shallow Draft Channel Project. The authorizing document for Shasta Dam provided for minimum releases of 5,000 cubic feet per second to maintain navigation depth. Releases for other Central Valley Project purposes generally exceed the minimum requirement, but releases specifically for navigation are occasionally needed. Little or no water is consumed for navigation uses.

Summary of Water Demands

Table 12 summarizes present and projected alternative applied water demands for the principal categories of consumptive water uses, i.e., urban, agricultural, and power plant cooling. Applied demands for recreation, fish, and wildlife are also included, but only as a single projection. The alternative projected applied water demands shown in Table 12 are summations of the values developed for each category of use.

Net water demands are used in Chapter VI to evaluate the relationship between water demand and water supplies. Net demand in each of the 11 hydrologic areas was calculated by a determination of (1) internal reuse of applied water, (2) conveyance losses, such as evaporation of surface water, water lost through leaks, etc, and (3) outflow from each hydrologic area.

Examples of reuse are return flows or drainage from an agricultural field that may be directly used in an adjacent field or that may be returned to a distribution system for use in a more distant field. An example of urban reuse is the discharge of treated waste water to rivers or streams that serve as sources of municipal and industrial water. Other examples include percolation of excess applied irrigation water (both agricultural and lawn or garden) where it may be recovered by pumping.

Of course, not all surplus surface or percolating water can be recovered for reuse. Waste water discharged to saline water bodies, and irrigation water that percolates into moisture-deficient soil, is lost to

[1] Chapter 893 Statutes of 1973

the freshwater supply. Agricultural water that flows out of a given area is also unavailable for reuse there but may be available for use in another area downstream.

Present and projected alternative net water demands for each of the State's hydrologic study areas are shown in Table 13. A comparison of Tables 12 and 13 shows that the total net demand is lower than the total applied demands in each hydrologic area except the Colorado Desert and San Francisco Bay areas. In the Colorado Basin, this is generally due to large conveyance losses and limited opportunities for reuse; in the San Francisco Bay area, conveyance losses slightly exceed reuse.

Table 12. 1972 and Projected Applied Water Demands by Alternative Futures (1,000 acre-feet)

Hydrologic study area	Urban				Agricultural				Power plant cooling				Fish, wildlife and recreation	Totals			
	I	II	III	IV	I	II	III	IV	I	II	III	IV		I	II	III	IV
North Coastal																	
1972	93	93	93	93	710	710	710	710	--	--	--	--	323	1,120	1,120	1,120	1,120
1990	104	102	101	97	720	720	710	710	--	--	--	--	359	1,180	1,180	1,170	1,170
2020	126	120	114	100	740	740	730	730	--	--	--	--	362	1,230	1,220	1,210	1,190
San Francisco Bay																	
1972	990	990	990	990	250	250	250	250	--	--	--	--	24	1,260	1,260	1,260	1,260
1990	1,480	1,460	1,430	1,340	290	280	290	280	--	--	--	--	37	1,810	1,770	1,750	1,660
2020	2,240	2,070	1,940	1,570	330	320	310	280	--	--	--	--	46	2,620	2,440	2,300	1,890
Central Coastal																	
1972	181	181	181	181	1,030	1,030	1,030	1,030	--	--	--	--	2	1,210	1,210	1,210	1,210
1990	308	300	289	252	1,240	1,200	1,190	1,200	--	--	--	--	3	1,550	1,500	1,480	1,460
2020	569	516	473	318	1,310	1,270	1,240	1,220	--	--	--	--	6	1,890	1,790	1,720	1,540
South Coastal																	
1972	2,370	2,370	2,370	2,370	920	920	920	920	18	18	18	18	6	3,320	3,320	3,320	3,320
1990	3,130	3,050	2,980	2,670	730	720	720	750	30	30	30	30	19	3,900	3,820	3,750	3,470
2020	4,830	4,360	4,120	2,980	530	510	520	520	80	40	0	0	23	5,470	4,940	4,660	3,520
Sacramento Basin																	
1972	470	470	470	470	6,020	6,020	6,020	6,020	0	0	0	0	125	6,610	6,610	6,610	6,610
1990	700	687	674	621	7,940	7,540	7,050	6,960	50	0	0	0	170	8,860	8,400	7,900	7,750
2020	1,040	968	908	702	9,080	8,350	7,540	7,410	140	60	50	0	174	10,400	9,550	8,670	8,290
Delta-Central Sierra																	
1972	173	173	173	173	2,470	2,470	2,470	2,470	20	20	20	20	6	2,670	2,670	2,670	2,670
1990	251	247	239	219	3,220	3,010	2,810	2,710	100	75	50	40	7	3,570	3,340	3,110	2,970
2020	537	490	451	323	3,700	3,540	3,250	3,020	150	100	110	70	9	4,400	4,140	3,820	3,420
San Joaquin Basin																	
1972	192	192	192	192	5,450	5,450	5,450	5,450	0	0	0	0	91	5,730	5,730	5,730	5,730
1990	295	287	279	249	6,620	6,390	6,040	5,750	0	0	0	0	94	7,010	6,770	6,410	6,090
2020	548	485	451	307	7,320	6,600	6,180	5,750	140	70	0	0	95	8,100	7,250	6,730	6,150
Tulare Basin																	
1972	363	363	363	363	10,890	10,890	10,890	10,890	0	0	0	0	43	11,300	11,300	11,300	11,300
1990	493	479	471	441	13,070	12,510	11,750	11,580	70	35	20	20	68	13,700	13,100	12,300	12,100
2020	798	718	679	530	14,870	13,720	12,360	11,750	240	130	60	60	70	16,000	14,600	13,200	12,400
North Lahontan																	
1972	23	23	23	23	420	420	420	420	--	--	--	--	11	454	454	454	454
1990	40	40	39	32	430	430	430	400	--	--	--	--	11	479	479	478	441
2020	68	59	54	35	430	430	430	400	--	--	--	--	13	507	498	493	444
South Lahontan																	
1972	89	89	89	89	310	310	310	310	0	0	0	0	4	399	399	399	399
1990	154	139	136	108	300	300	300	300	10	10	10	0	16	478	463	460	422
2020	387	326	306	143	250	250	250	250	100	50	0	0	22	762	651	581	418
Colorado Desert																	
1972	99	99	99	99	3,220	3,220	3,220	3,220	0	0	0	0	20	3,340	3,340	3,340	3,340
1990	148	142	139	126	3,320	3,320	3,320	3,320	130	70	40	40	22	3,620	3,560	3,530	3,510
2020	275	246	230	173	3,320	3,320	3,320	3,320	250	130	130	80	26	3,880	3,730	3,710	3,600
State Total																	
1972	5,040	5,040	5,040	5,040	31,700	31,700	31,700	31,700	38	38	38	38	655	37,400	37,400	37,400	37,400
1990	7,100	6,930	6,770	6,160	37,900	36,400	34,600	34,000	390	220	150	130	806	46,200	44,400	42,400	41,100
2020	11,400	10,400	9,730	7,170	41,900	39,000	36,100	34,600	1,100	580	350	210	846	55,300	50,800	47,000	42,900

Table 13. 1972 and Projected Net Water Demands by Alternative Futures
(1,000 acre-feet)

Hydrologic study area	1972	Alternative 1990 future				Alternative 2020 future			
		I	II	III	IV	I	II	III	IV
North Coastal	940	990	990	980	980	1,040	1,030	1,010	1,000
San Francisco Bay	1,270	1,820	1,780	1,760	1,660	2,630	2,450	2,310	1,900
Central Coastal	950	1,240	1,200	1,180	1,150	1,560	1,480	1,410	1,250
South Coastal	3,030	3,770	3,700	3,640	3,390	5,200	4,720	4,480	3,460
Sacramento Basin	5,780	7,610	7,200	6,800	6,630	9,030	8,240	7,530	7,080
Delta Central Sierra	2,270	3,110	2,900	2,700	2,580	3,860	3,630	3,360	3,010
San Joaquin Basin	4,650	5,510	5,350	5,120	4,960	6,280	5,710	5,320	5,030
Tulare Basin	7,300	9,200	8,800	8,290	8,180	11,000	10,110	9,160	8,700
North Lahontan	430	450	450	450	420	480	470	470	420
South Lahontan	280	330	330	320	300	510	430	370	290
Colorado Desert	4,070	4,240	4,180	4,150	4,140	4,430	4,300	4,290	4,210
State Totals	31,000	38,300	36,900	35,400	34,400	46,000	42,600	39,700	36,400

V. SOURCES OF WATER AND WATER MANAGEMENT

For many years, California's water needs have been met by the development of conventional water resources, i.e., the storage and diversion of surface water and the extraction of ground water. Today, other sources have begun to emerge as potential sources of water supply. These include waste water reclamation, desalting, geothermal resources, and weather modification.

In addition, more effective methods for the use of existing water supplies are being developed to help meet California's water-supply and water-control requirements. These various sources of water supply and improved water management practices are discussed in the following paragraphs.

Surface Water Regulation

Of the various methods of water supply augmentation, the regulation of surface water by dams and reservoirs has been the most widely practiced in California. An extensive network of local, state, and federal storage reservoir provides a significant degree of control of the runoff of most streams in the more highly developed areas of the State. At the present time, there are 1,090 reservoirs under state jurisdiction (in regard to safety), almost all of which were financed and constructed by local water agencies, and 150 federal reservoirs. Of these, 1,240 reservoirs, the storage capacities of 141 range from 10,000 to 100,000 acre-feet, 45 range from 100,000 to 1 million acre-feet, and 10 exceed 1 million acre-feet.

During the past four years, two multipurpose projects, Martis Creek Lake and Mojave Lake, were completed by the U. S. Corps of Engineers. Local agencies also completed a number of projects, mainly for distribution of water in their respective service areas. Many of these distribution systems were constructed to serve water supplied by the State Water Project. During the same period, 29 water projects financed under the State Financial Assistance to Local Projects Program (Davis-Grunsky Act) were completed.

Most of the larger surface water projects are located in the Central Valley. Additional projects now under construction include Auburn Dam on the American River, New Melones Dam on the Stanislaus River, Buchanan Dam on the Chowchilla River, Hidden Dam on the Fresno River, Warm Springs Dam on a tributary of the Russian River, and Indian Valley Dam on North Fork Cache Creek. Major water transfer facilities under construction by the Bureau of Reclamation include the Tehama-Colusa Canal, the Folsom South Canal, and the San Luis Drain. Construction of the Cross Valley Canal has been initiated by the Kern County Water Agency.

Development of additional surface water is now, and will probably continue to be, limited by both the increasing costs of constructing facilities and the conflicting uses of water and land. For example, North Coastal rivers in the California Wild and Scenic Rivers System collect about 25 percent of the State's natural runoff. The water in these streams is committed to maintenance of the wild and scenic rivers system.

Most of the remaining unregulated streams outside of the North Coastal area are in the Central Valley. A number of possible alternative projects have been considered for regulation of these streams; however, none is presently under construction, nor is it likely that all of them would be constructed. These possible future projects in the Central Valley are as follows:

Project	Stream System
Cottonwood Creek Project	Cottonwood Creek
Dutch Gulch Reservoir	Main Stem
Tehama Reservoir	South Fork
Millville Reservoir	South Cow Creek
Wing Reservoir	Inks Creek
Schoenfield Reservoir	Red Bank Creek
Gallatin Reservoir	Elder Creek
Glenn Reservoir-Sacramento River Diversion	Stony and Thomes Creeks-Sacramento River
Marysville Reservoir	Yuba River
Los Banos Reservoir	Los Banos Creek
Cosumnes River Project	Cosumnes River
Nashville Reservoir	Main Stream
Pi Pi Reservoir	Middle Fork
Aukum Reservoir	South Fork
East Side Division-Central Valley Project	Sacramento-San Joaquin Delta

The list of possible projects also includes three in the North Coastal Area; these are Butler Valley Reservoir on the Mad River and Dos Rios and English Ridge Reservoirs on the Eel River. However, the Eel River is part of the California Wild and Scenic Rivers System. The Legislature has directed that in 1985, the Department of Water Resources report on the need for development of the Eel River so that its continuance in the Wild and Scenic Rivers System can be reconsidered.

Ground Water

The increased use of ground water in California is limited by the recharge capabilities of some of the State's individual ground water basins. However, depletion or mining, which is carried out in some water-deficient areas, may provide economic interim water supplies in such areas. When supplemental supplies are required in areas overlying ground water basins, four methods of basin operation are generally used.

These are:

- Safe yield based on natural replenishment.
- Temporary overdraft, or mining, pending development of supplemental surface supplies.
- Court-ordered regulation of withdrawals.
- Sustained yield using natural replenishment and planned or incidental recharge with imported water.

Improved uses of ground water are the objectives of several current ground water management investigations by the Department of Water Resources. A specific example of one such investigation is the use of surplus Northern California water for ground water recharge in areas south of the Tehachapi Mountains for subsequent withdrawal to either (1) offset water deficiencies during possible shutdown of the California Aqueduct, or (2) defer capital expenditure for construction of additional State Water Project conservation facilities that would be required during critically dry periods to meet delivery commitments. The investigation is being carried out cooperatively with water service agencies in Southern California.

Other studies by the Department of Water Resources include:

- A state-federal cooperative investigation of a canal (Mid-Valley Canal), which extends from the California Aqueduct to the eastern San Joaquin Valley, to alleviate long-time ground water overdrafts in the eastern Tulare Basin.
- Cooperative investigations, with federal and local water agencies, of hydrologic, geologic, and water-quality data on ground water in all parts of California.
- Evaluation of the probability of obtaining producing domestic wells in mountainous fractured-rock areas.
- Protection of ground water from quality degradation, e.g., studies of (a) sea-water intrusion barriers, (b) sanitary landfills, (c) the effects of deep injection of oil-field wastes, (d) well construction practices, and (e) land subsidence.
- Cooperative mathematical modeling studies of major ground water basins.
- Monitoring of subsidence of land areas caused by ground water pumping.

The quality of ground water in California is generally good, although scattered areas of poor-quality water may be found throughout the State, particularly in the southeastern desert areas, where the dissolved mineral content of some ground water bodies may range up to several thousand parts per million. In many parts of the State, heavy pumping of ground water is causing overdrafts of local ground water basins. In coastal areas, this excessive pumping is leading to sea water intrusion. In the San Joaquin Valley, where the annual overdraft approaches 1.3 million acre-feet, ground water pumping is causing deep subsidence in many areas.

Efficient management of surface and ground water resources will require comprehensive investigation of the institutional, legal, economic, and financial effects of management proposals. The institutional problems will require extensive dialogue among local water service agencies and those with statewide jurisdiction, such as the Department of Water Resources and the U.S. Bureau of Reclamation. Although ground water management at the lowest possible governmental level is frequently advantageous, regional management may be necessary in many areas if maximum use of ground water resources is to be achieved. Regional authority might be established by (a) legislation, (b) stipulation by a coalition of adjacent water service agencies, or (c) the legislative processes associated with water rights permits administered by the State.

Waste Water Reclamation

In this day of special concern for the environment, the reclamation of waste water is a promising source of additional water supplies. The reclamation of waste water not only provides pollution control but also can augment natural water supplies, thus reducing the need for development of new sources of water. As used in this bulletin, "waste water reclamation" means the planned renovation of waste water with the intent of producing usable water for a specific beneficial purpose.

Of course, much of the water used in California is returned to the freshwater cycle, either directly after its use or following treatment. This includes most of the return waters from irrigated land and the treated waste from cities, where waste water is returned to freshwater supplies for further use. Although treatment of this waste water tends to enhance water quality, it does not create a new supply. Only when waste water would otherwise be discharged to saline water, or when it has been so degraded that it cannot be discharged to freshwater, does its reclamation create a new supply.

The amount of water that may be reclaimed is limited. Up to 50 percent of a given municipal water supply is used consumptively and is therefore unavailable for reclamation. Of the waste water available for reclamation, about 15 percent will be chemically unsuitable. An additional 20 to 30 percent will be required to carry off concentrated wastes and prevent accumulation of salts in the soil. Accordingly, only about 60 percent of the available waste water could be reclaimed.

Table 14 shows the disposition of treated waste water discharged in 1972. As shown, almost 70 percent of the 2.5 million acre-feet of treated waste effluent produced during 1972 was discharged into the ocean and to saline bays and estuaries. It is the reclamation of this waste water (1.7 million acre-feet in 1972) that offers potential as a new source of water.

In general, the amount that may be reclaimed is limited by (a) the quality of the waste water, (b) the cost of treatment, (c) the cost of conveyance and treatment, and (d) the price that potential users are willing and able to pay, and (e) public acceptance of the proposed use.

The costs of reclaimed water vary widely, depending on the quantity and quality of the waste water and the intended use. Present costs range from:

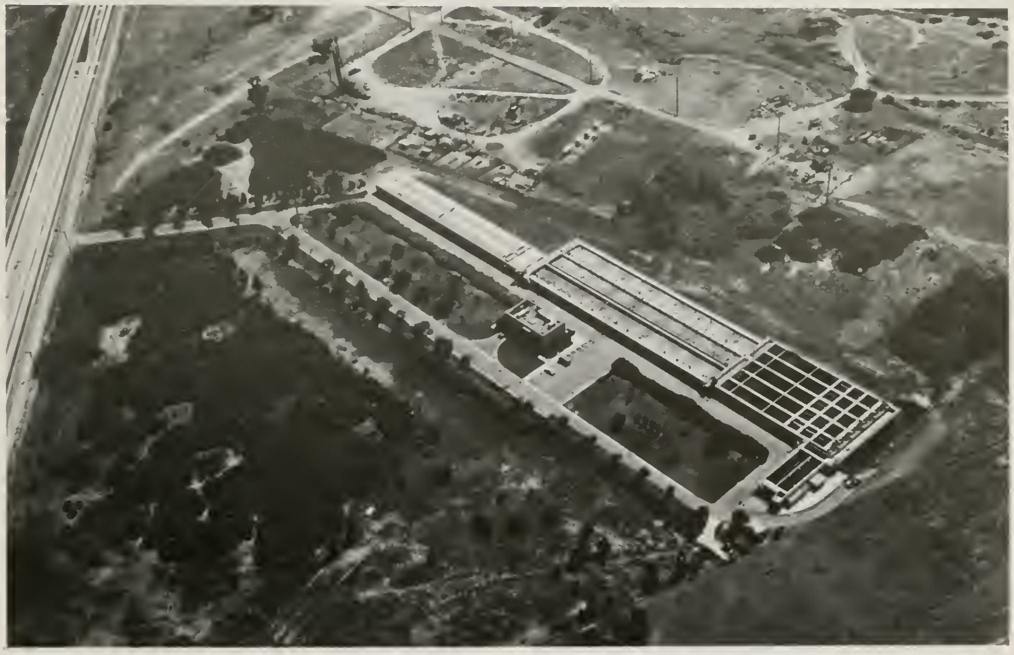
- $2 to $5 per acre-foot in areas where reclaimed water can be used for irrigation near a treatment plant.
- $20 to $40 per acre-foot where extensive treatment, storage, transportation, and disposal are required.
- More than $100 per acre-foot where more extensive treatment, such as desalting, is required.

Table 14. Summary of Urban Waste Water Production, Disposal, and Reclamation in 1972
(1,000 acre-feet)

Hydrologic study area	Waste water produced	Waste water reclaimed			Waste water discharge	
		Intentional	Incidental	Total	Net[a]	To saline waters[b]
North Coastal	73	1	6	7	72	66
San Francisco Bay	583	8	32	40	575	540
Central Coastal	114	5	35	40	109	62
South Coastal	1,287	57	152	209	1,230	1,066
Sacramento Basin	106	12	86	98	94	0
Delta-Central Sierra	131	8	121	129	123	0
San Joaquin Basin	60	26	32	58	34	0
Tulare Basin	116	45	45	90	71	0
North Lahontan	11	6	3	9	5	0
South Lahontan	20	7	8	15	13	0
Colorado Desert	22	6	12	18	16	1[c]
Total	2,523	181	532	713	2,342	1,735

[a] The amount of waste water produced less the amount used in intentional reclamation.
[b] Ocean, bays, and estuaries.
[c] Discharges to Salton Sea and Colorado River.

At present, reclaimed water is used principally for agricultural, industrial, municipal, and recreational pursuits. Agricultural uses include the irrigation of (1) pasture, (2) fodder, fiber, and seed crops, (3)



Whittier Narrows waste water reclamation plant crops grown well above the ground, such as fruits, nuts, and grapes, and (4) crops that are processed so that pathogenic organisms are removed prior to human consumption. The direct use of reclaimed water for domestic use is not permitted in California, because public health authorities are uncertain that virus and other disease-producing agents can be eliminated from waste water.

Industrial uses of reclaimed water include cooling water, process wash water, boiler feed water, fire protection, and secondary product recovery. These are carried out chiefly at metalurgical manufacturing and fabrication plants, electric-power generation plants, oil refinaries and petro-chemical plants, lumber mills, and in mining and quarrying. Municipal and recreational uses include the irrigation of parks, freeway landscaping, golf courses, and athletic fields, and the creation of recreational lakes.

The direct, intentional use of reclaimed water in the 11 hydrologic areas of California during 1972 is shown in Table 15.

Table 15. Intentional Use of Reclaimed Water in 1972
(Acre-feet)

Hydrologic area	Industrial	Irrigation			Ground water recharge	Recreation	Log deck sprinkling	Wildlife habitat	Total
		Crops	Landscape	Golf course					
North Coastal	100	500	--	--	--	--	--	--	600
San Francisco Bay	--	3,200	1,000	200	--	3,800	--	--	8,200
Central Coastal	--	5,400	--	--	100	--	--	--	5,500
South Coastal	2,800	20,200	9,600	2,700	21,200	700	--	--	57,200
Sacramento Basin	--	5,000	--	--	--	--	4,900	1,700	11,600
Delta-Central Sierra	--	8,400	--	--	--	--	--	--	8,400
San Joaquin Basin	--	25,300	200	200	--	--	--	--	25,700
Tulare Basin	--	44,100	200	200	900	--	--	--	45,400
North Lahontan	--	3,600	--	--	--	--	2,800	--	6,400
South Lahontan	--	2,600	--	3,600	400	--	--	--	6,600
Colorado Desert	900	3,600	--	1,600	200	--	--	--	6,300
Totals	3,800	121,900	11,000	8,500	22,800	4,500	7,700	1,700	181,900

Future opportunities for waste water reclamation will be most productive in areas where (1) water is costly or scarce, (2) waste water is discharged to saline or brackish waters, and (3) the quality of the initial water supply is good enough to enable treatment by conventional processes. In the San Francisco Bay, Los Angeles, and San Diego metropolitan areas, waste water reclamation offers particular potential as a supplemental water supply. These heavily populated areas depend to some extent now, and will depend to a greater extent in the future, on good-quality water imports. Furthermore, much of the waste water produced in these areas is of reusable quality.

Both the San Joaquin and Tulare Lake Basins offer potential for the reclamation of agricultural waste water. Recent estimates indicate that, at the 1970 level of development, about 87,000 acre-feet of agricultural waste water was generated each year in these two basins. This is expected to increase to 400,000 acre-feet by 1990. Two possible alternatives exist for the use of this waste water:

- It could be desalted to provide additional water supplies.
- It could be softened and used for powerplant cooling.

Reclaimed waste water can help meet water requirements, help improve water quality, and help enhance the environment. Table 14 shows that during 1972, about 7 percent of the waste water produced in California, or about 181,000 acre-feet, was intentionally reclaimed for specific beneficial uses.

Desalting

Desalting is used to produce fresh water in certain areas of the world, e.g., Saudi Arabia, Kuwait, the Caribbean Islands, where its cost is competitive with the high costs of alternative sources of water. In California, desalting has been used on a limited basis, because the present costs of desalting generally are far higher than the costs of surface or ground water supplies.

Certain California industries use small-scale desalting processes to produce distilled, bottled water. In addition, most coastal power plants have sea-water distillation facilities for the production of boiler-feed water and for other in-plant uses. Total state production of desalted water is about 2,000 to 3,000 acre-feet per year.

Small-scale desalting has been used in a few California communities, e.g., an electrodialysis plant and reverse osmosis test unit at Coalinga and a standby sea-water distillation unit on Catalina Island. The Coalinga units were used to desalt brackish ground water until surface-water imports became available to the city in 1971. However, there are no municipal applications of desalting in California today.

Two factors limiting the expansion of desalting today are the high cost and the large quantities of energy required. Until about 1970, refinements in desaulting technology were steadily decreasing the unit costs of desalted water. For example, in 1960, the estimated costs of producing fresh water in a small-capacity plant was about $6.00 per 1,000 gallons; by 1970, this had been reduced to about $1.00 per 1,000 gallons. Today, however, inflation and the rising costs of fuel have combined to drive unit costs upward again.

The Department of Water Resources began desalting research in 1957. The following year the Department began a program of close cooperation with the federal Office of Saline Water (now incorporated into the Office of Water Research and Technology). The Department participated with the Office of Saline Water in funding and operation of a sea-water conversion plant at Point Loma, near San Diego, and the San Diego Saline Water Test Facility.

The Department of Water Resources is also participating with the Office of Saline Water and the University of California in studies of the feasibility of desalting agricultural waste water. The studies are carried out at a test station in Firebaugh in the San Joaquin Valley. One study at Firebaugh, combining an ion-exchange process with reverse osmosis desalting, has resulted in 90 percent removal of salt from agricultural waste water. The Department is also cooperating with the Metropolitan Water District of Southern California in studies to determine the feasibility of desalting Colorado River water to improve its quality.

The Department recently inventoried 111 small and medium-size California communities where excessive salts in municipal water supplies have created serious water-quality problems. A report on the possibility of using small-scale desalting to improve water quality in 10 of these communities will be published soon.

In the future, desalting processes may be increasingly used for special tasks as metropolitan areas find it necessary to improve management of existing water supplies. There will be a need to provide salt balance in ground water basins, to improve water quality, to reuse water, and to meet regulatory requirements for the discharge of waste water. In some cases these processes could be accomplished by desalting. Desalting processes will also play an increasing role in the treatment of agricultural waste waters. All in all, desalting will probably play an increasing role in water resource management over the next 10 to 30 years, but is not expected to be a major source of supplemental water supply.

Geothermal Water Potential

Geothermal energy is the natural heat generated beneath the surface of the earth. In certain areas of California, subsurface temperatures rise sharply with depth; in such areas, superheated ground water comes to the surface as hot springs and geysers. The production of fresh water from saline ground water in such geothermal areas offers another potential source of water supply.

Necessary conditions for production of fresh water include a source of geothermal heat, an adequate supply of brine, and a favorable market for fresh water. The most economical development of geothermal resources would result from a facility that combines the production of power and water and, possibly, mineral by-products. The hot mineralized water could be distilled with its own heat, or the heat could be used to distill other mineralized water or for the generation of electrical energy. The distillation process would also produce large quantities of waste brines; a satisfactory method for their disposal would be essential.

Of the three major geothermal areas in California which have been investigated for commercial exploitation—the Geysers in Sonoma County, the Mono Lake-Long Valley-Casa Diablo area, and the southern Imperial Valley—only the Imperial Valley appears to have sufficient quantities of hot subsurface brine to enable large-scale production of water. At least nine geothermal anomalies—areas beneath the surface where ground temperatures are above normal as a result of near-surface penetration of heat from the hot magma of the earth's core—have been identified between the Salton Sea and the Mexican Border.

Other parts of the Imperial Valley have been identified as potential areas for further investigation. Estimates of the hot geothermal brines in the basin range from 1 to 5 billion acre-feet; quantities recoverable and usable at temperatures of 300°F or higher have been estimated at 200 million acre-feet.

The Department of Water Resources is monitoring the programs conducted by private and public entities with the objective of establishing the physical and economic feasibility of geothermal resources development in the Imperial Valley as soon as possible. Also, to further define conditions at the Dunes Anomaly, the Department drilled a 2,000 foot test hole in 1972. Maximum temperature encountered in the test hole was 218° F. Cores fluid samples, and logs for this well were collected and analyzed, and preliminary results were published in a joint report by the Department and the University of California, Riverside.

The U. S. Bureau of Reclamation has been conducting a fresh-water-production research project in cooperation with the U. S. Office of Saline Water at the Mesa Anomaly in the Imperial Valley. In 1972, a geothermal well 8,000-feet deep was drilled and completed. Pressure and temperature were adequate to produce steam and brines with a salinity of about 17,000 milligrams per liter. In 1973, two experimental desalination units, each capable of producing 20,000 to 50,000 gallons per day, were erected near the well to test the operation of distillation processes.

If geothermal fluids in the Imperial Valley prove to be an economical source of water, they might augment the Colorado River supplies now used in Southern California and alleviate the increasing water quality problems there. Fresh water could be (1) added to the Colorado River, (2) used as a direct supply to meet municipal and industrial demand in the Imperial Valley, or (3) blended with Colorado River water in the All-American Canal system.

Further investigation will be required to establish the feasibility of large-scale use of the geothermal resources in the Imperial Valley. More geologic and engineering knowledge is needed to (1) refine estimates of the amount of brines and of the utility of the heat contents, (2) solve scaling and corrosion problems, (3) develop economical and acceptable methods of disposing of geothermal pollutants and solve other environmental problems, (4) determine costs of fresh water production, and (5) establish the economic feasibility and justification of such production. The magnitude of these tasks indicates that large-scale production of fresh water is still some years away.

Weather Modification

During the past 25 years, the possibility of creating or increasing precipitation by cloud seeding has been the subject of considerable research and development. So far, experiments in California have consisted primarily of efforts to (a) increase precipitation from individual clouds or storms, (b) clear fog at airports, and (c) suppress lightning and hail storms. The most common method is the seeding of clouds with silver iodide, sulfur trioxide, or both, from either aircraft or ground-based generators. During the 1971–72 season, 12 weather modification projects were carried out in California by various public and private contractors. Six of these projects were efforts to increase precipitation.

The role of the Department of Water Resources in weather modification research is a varied one. During 1971–72, the Department funded several research activities by the California State University Fresno Foundation. The studies were conducted as part of Project Skywater, a nationwide program of the U. S. Department of Interior. In addition to its studies of winter storm modification, the Fresno Foundation has also studied the potential of producing or increasing precipitation from summer cumulus clouds over the central Sierra Nevada.

The Department is now planning to conduct a pilot project to determine the effects of cloud seeding above the Feather River Basin. Subject to completion of a satisfactory Environmental Impact Report, seeding of a portion of productive storms is expected to begin during the fall of 1975.

The effectiveness of weather modification projects is difficult to evaluate because of great variety of natural weather and rainfall patterns. Frequently, similar experiments produce conflicting results. Moreover, a number of legal and technical questions remain unresolved. An important legal question relates to the responsibility of operators for increasing flood flows and for the possible decrease in precipitation in areas downwind from target areas.

Management Concepts and Practices

In addition to the various sources of water discussed in the preceding paragraphs, new management practices are being studied and developed to enable more effective use of water supplies already available. As new sources of water become more scarce, better management of available water supplies will help meet California's increasing water requirements.

More Effective Use of Water

More effective use of existing water supplies will help meet increasing water demands. Improved methods of operation include:

Improved farming and irrigation practices.

- Controlled application of irrigation water to wet only the crop root zone.
- Better timing of water applications to reduce wasted runoff and deep percolation.
- Improved soil structure to reduce the rate of water intake.
- Lined irrigation ditches to reduce seepage losses.

Improved use of urban water supplies.

- Use of pricing policies, such as metering, to discourage wasteful practices.
- Use of information programs to encourage conservation of water.

Expanded use of lower quality water for uses that do not require high-quality water.

- Cooling water for power plants and industry.
- Blending with higher quality water to obtain usable water supplies.
- Irrigation of golf courses, parks, freeway landscaping, etc.
- Creation of wetlands and wildlife refuges.

More Effective Use of Facilities

The Department of Water Resources and other water agencies are studying new methods for more efficient operation of water development facilities, i.e., reservoirs, aqueducts, canals, etc., in an effort to increase the yield of water projects. Examples of more effective operations are as follows:

1. Most water projects in California are operated independently by individual water agencies. The coordinated operation of individual projects could increase water yields. For example, coordinated operation of State Water Project and federal Central Valley Project facilities enables maximum water yields in the Sacramento-San Joaquin Delta.

2. During winter and early spring, water conveyance systems frequently have unused capacity that could be used to transport surplus streamflow from areas with excess water supplies. Through water exchanges and coordinated operation of facilities, surplus water could be conveyed for off-season storage in surface or ground water reservoirs.

Ground Water Modeling

The relationships among the physical properties of a ground water basin can be approximated by equations. Therefore, a mathematical model of a ground water basin, programmed on a high-speed electronic computer, can be used to verify an analysis and to test a wide variety of methods for using the ground water basin in conjunction with surface supplies and distribution and storage facilities.

The use of mathematical models has led to an improvement in the approach to ground water basin management, which involves the planned use of ground water in storage in conjunction with local and imported surface water, and the use of subsurface aquifers in conjunction with pipelines and canals for movement of water. Management of a ground water basin may include one or more of the following objectives.

- Integration of ground water supplies with water from other sources to obtain the lowest cost water supply.
- Use of a ground water reservoir to store excess water and thus increase the total available supply.

Smith River at the junction of the North Fork and Middle Fork

- Mining of water previously stored to defer construction of import or distribution facilities.
- Control of the movement of water within the ground water basin, including the intrusion of sea water.
- Prevention of adverse salt build-up.
- Operation of a ground water basin to prevent or relieve drainage or subsidence problems.

The Department of Water Resources, in cooperation with local agencies, has developed mathematical models that permit complex evaluations of alternative operational plans. The studies are enabling local agencies to make management decisions based on fact instead of speculation. Decisions on how much imported water to purchase, when to purchase it, and where to use it have been influenced by modeling studies of many areas of the State. On a statewide basis, the results of modeling studies provide valuable knowledge on the overall role of ground water in satisfying demands for future water supply and storage.

Waterway Management Planning

The objective of waterway management planning is to protect and enhance certain rivers and streams and their immediate adjacent land areas. In 1971, the Legislature directed the California Resources Agency to prepare detailed waterway management plans for certain streams in the North Coastal and northern San Francisco Bay Hydrologic Areas. Then, in 1972, the Resources Agency was directed to prepare and administer management plans under legislation establishing the State Wild, Scenic, and Recreational System.

The Resources Agency's waterway management plans are designed to:

- Protect and enhance scenic, recreational, geologic, fish and wildlife, historic, and archaeological values.
- Help maintain and enhance water quality.
- Provide river-oriented recreation opportunities while protecting other river quality values.
- Maintain all streams in the State Wild and Scenic Rivers system in a natural and free-flowing condition.
- Identify desirable measures for control of floods and augmentation of streamflow.

The Resources Agency, in cooperation with appropriate local and federal agencies, is now preparing plans for the Smith and Klamath Rivers. After public hearings, the Smith River plan is expected to be submitted to the Legislature for consideration during the 1975 session.

Flood Control Management

Two general categories of flood control measures are used to prevent flood damage—structural and nonstructural. The first category includes reservoirs and detention basins; floodways and bypasses, levees, and river channel improvements. Nonstructural measures include flood plain zoning to prevent development, flood forecasting and warning procedures, flood proofing, and flood insurance. A combination of structural and nonstructural measures is frequently the most effective method of preventing flood losses.

Over the years, federal and local agencies have dominated the planning and construction of flood-control structures in California, with state financial aid for the costs of land, easements, and rights-of-way. The Cobey-Alquist Flood Plain Management Act of 1965, which is administered by the Department of Water Resources, directs local governments to regulate development in flood plains prior to the construction of local projects as a condition to receiving state financial aid.

In July 1974 the Department of Water Resources began a 3-year study of the flood damage-prevention problem in California. The study, which will be conducted in cooperation with local flood-control agencies, will inventory existing and proposed flood-control works, estimate the degree of protection from flooding, identify residual flood problems, and examine and evaluate flood management concepts as they might resolve existing problems.

Water Quality Control Planning

The State Water Resources Control Board regulates the activities and factors that affect, or that may affect, the quality of the waters of the State, in order to attain the highest reasonable water quality considering all demands being made and to be made on these waters and the total values involved. Water quality and quantity are so interrelated that they must be considered together; this was recognized by the Legislature, which charged the State Board with responsibility for both quantity allocation (water rights administration) and control of quality.

The Porter-Cologne Water Quality Control Act of 1969 established the present control mechanism. The Act requires the formulation and adoption of water quality control plans by each of the nine Regional Water Quality Control Boards for all areas with each region. The plans become effective upon approval of the State Board and will become a part of the California Water Plan when reported to the Legislature.

The comprehensive plans for each of the 16 basins comprising the State have been under preparation since May 1972 and will be completed by December 1974. The plans will be published as reports and are expected to be adopted and approved within a few months after publication. The plans will be assessed and revised as necessary to reflect current conditions and technology.

VI. WATER SUPPLY AND SUPPLEMENTAL DEMANDS

If the average total statewide runoff (Figure 3) of almost 71 million acre-feet were available for use at all the right times and places, it would meet all foreseeable future statewide demands. However, natural storm runoff occurs neither at the precise time of need nor in the right locations. Most of California's runoff occurs during winter and early spring, whereas peak demands occur during the summer. Moreover, most runoff occurs in the northern part of the State, whereas almost 75 percent of the demand occurs south of Sacramento.

Table 16 presents a comparison of total available water supplies and total use and commitments for the 1972 level of use.

Table 16. Total Water Supply and Present Use and Commitments (millions of acre-feet)

Water supply		Present use and commitments	
Average natural runoff		1972 use (depletions)	27.0
North Coastal Area	27.2		
Sacramento Basin	22.4	Wild and scenic rivers	17.8
Remaining Central Valley	11.2		
Other areas	10.0		
Total runoff	70.8	Salinity repulsion	3.4
Imports from Colorado River	4.4		
		Outflow to Nevada	1.2
Inflow from Oregon	1.4		
		Total use and commitments	49.4
Total water supply	76.6	Remaining water supplies	27.2

Theoretically, the balance of 27.2 million acre-feet shown in Table 16 represents the runoff available for regulation to meet increased future water demands. However, about one-half of it cannot be captured because (1) the runoff occurs in remote areas, e.g., coastal watersheds or desert areas, where neither regulation nor conservation is possible or (2) the runoff occurs during infrequent flood flows, which cannot be regulated or conserved.

Available Water Supplies

The measure of water supplies used in the following paragraphs is in terms of *dependable* water supply, i.e., *the quantities of water that can be provided from various sources to a water service area on a schedule that will meet demands in that area.* The water supplies discussed for 1972 represent the estimated quantities required for the current level of use and are not, in all cases, the actual quantities delivered during that rather dry year.

Surface Water

Of the total statewide 1972 net water requirement of 31 million acre-feet, some 23.3 million acre-feet was supplied by surface water projects. As briefly described in Chapter I, these include (1) local water development by local water agencies, (2) long-distance imports by local agencies, (3) the Central Valley Project and other federal water projects, and (4) the California State Water Project. Major surface water projects are shown in Plate 1.

Ground Water Safe Yield

Ground water provides about 40 percent, or some 15 million acre-feet, of California's applied water needs. About one-third (5.2 million acre-feet) of the total is supplied from safe yield of the ground water basins. One-half of the total pumping comprises reuse of deep percolation of irrigation water and of losses from canals and distribution systems serving urban and agricultural areas. The remaining portion (2.2 million acre-feet) is overdraft, i.e., ground water taken out of storage beyond the current recharge capability. Together, the overdraft and safe yield comprise about 7.4 million acre-feet, or about 24 percent of the net water use in California. An additional 7.6 million acre-feet of annual ground water extraction constitutes reuse of water percolated from applications of excess surface water.

The complete extent of the State's ground water resources is not fully known. Whereas the known areas of water-bearing underground strata have been generally delineated, knowledge of storage capacity is limited to (1) the basins most heavily used, where the need is greatest, and (2) the depths considered to represent a limit to economic pumping, even though water may be found at far greater depths.

Other Sources of Water

Waste Water Reclamation. During 1972, about 180,000 acre-feet of waste water was reclaimed, most of which was used for the irrigation of fodder, orchards, fiber, seed and other nonedible crops. Whereas in the past, declaimed water at inland areas has been included as part of reuse of net water supplies, in Bulletin No. 160-74, the quantities of waste water reclaimed for a specific beneficial use are considered as a separate item of supply. The projected quantities shown in Table 17 include only those quantities produced by planned reclamation projects, i.e., water reclaimed for a specific use, and do not include incidental reuse, such as treated waste water returned to a river or irrigation return water that is mixed with incoming supplies.

Table 17. Summary of 1972 and Projected Water Supplies, Net Water Demands and Supplemental Demands by Hydrologic Study Areas
(1,000 Acre-feet Per Year)

Items	North Coastal			San Francisco Bay			Central Coastal			South Coastal			Sacramento Basin			Delta-Central Sierra		
	1972	1990	2020	1972	1990	2020	1972	1990	2020	1972	1990	2020	1972	1990	2020	1972	1990	2020
Dependable water supplies																		
Local surface water developments	390	390	400	170	170	170	54	54	54	90	90	90	2,480	2,610	2,790	1,330	1,370	1,420
Imports by local water agencies	2	2	2	700	700	700	--	--	--	1,720	940	940	9	9	9	--	--	--
Ground water safe yield	140	160	180	330	340	340	720	750	750	930	930	930	1,190	1,360	1,390	630	610	610
Central Valley Project[1]	--	--	--	80	140	270	--	--	--	--	--	--	2,700	3,170	3,380	130	800	760
Other federal water developments[1]	430	430	430	100	230	230	55	55	55	20	20	20	200	190	190	110	120	120
State Water Project[2]	--	--	--	130	230	260	0	87	87	190	2,340	2,340	1	38	40	--	--	--
Waste water reclamation	--	--	--	8	54	55	6	7	8	57	81	81	11	13	18	8	10	18
Desalting	--	--	--	--	--	--	--	--	--	0	16	16	--	--	--	--	--	--
Total dependable water supplies	960	980	1,010	1,520	1,860	2,030	830	950	950	3,010	4,420	4,420	6,590	7,390	7,820	2,210	2,910	2,930
Alternative Future I																		
Total net water demand	940	990	1,040	1,270	1,820	2,630	950	1,240	1,560	3,080	3,770	5,200	5,780	7,610	9,030	2,270	3,110	3,860
Supplemental demand	2	20	30	9	80	600	140	290	610	160	0	780	240	500	1,210	120	220	930
Reserve supply[3]	20	10	0	260	120	0	20	0	0	90	650	0	1,050	280	0	60	20	0
Alternative Future II																		
Total net water demand	940	990	1,030	1,270	1,780	2,450	950	1,200	1,480	3,080	3,700	4,720	5,780	7,200	8,240	2,270	2,900	3,630
Supplemental demand	2	20	30	9	70	480	140	250	530	160	0	300	240	360	730	120	120	710
Reserve supply[3]	20	10	10	260	150	60	20	0	0	90	720	0	1,050	550	310	60	130	10
Alternative Future III																		
Total net water demand	940	980	1,010	1,270	1,760	2,310	950	1,180	1,410	3,080	3,640	4,480	5,780	6,800	7,530	2,270	2,700	3,360
Supplemental demand	2	20	20	9	70	370	140	230	460	160	0	60	240	290	530	120	110	550
Reserve supply[3]	20	20	20	260	170	90	20	0	0	90	780	0	1,050	880	820	60	320	120
Alternative Future IV																		
Total net water demand	940	980	1,000	1,270	1,660	1,900	950	1,150	1,250	3,080	3,390	3,460	5,780	6,630	7,080	2,270	2,580	3,010
Supplemental demand	2	20	20	9	30	120	140	200	300	160	0	0	240	210	320	120	80	280
Reserve supply[3]	20	20	30	260	230	250	20	0	0	90	1,030	960	1,050	970	1,060	60	410	200

[1] Facilities existing or under construction; amounts include water rights and exchange supplies in the Central Valley furnished from CVP facilities.
[2] Facilities definitely planned for construction and additional conservation facilities authorized to meet contractual commitments.
[3] Potentially available to certain portions of the hydrologic study area to meet additional water demands; usually not available to other areas of supplemental demand because of a lack of physical facilities and/or institutional arrangements.

Desalting. At the present time, no municipal water in California is supplied by desalting, and because of the high cost and intensive uses of energy, no new significant developments are expected. However, because a large desalting facility in Orange County is nearing operational status, 16,000 acre-feet of desalted water supplies are included in the projected supplies shown in Table 17.

Summary

Table 17 is a summary of present and projected (a) water supplies, and (b) net water demands in the 11 hydrologic areas of California. The quantities of water shown as reserve supplies represent, in a given hydrologic area, either (a) supplies in excess of demand or (b) supplies that exceed the capability of available conveyance or distribution facilities. The reserve supply is valid at face value only in a designated service area. Its use in another service area would entail a number of institutional arrangements as well as physical transfer facilities.

The statewide water supply and demand picture under each alternative future is summarized in Figure 7. The principal sources of water are indicated and compared with total net water demands. The difference between water supply and net water demand is the supplemental demand. By 1990, the Colorado River supply will be reduced from the present 5.15 million acre-feet to about 4.4 million acre-feet, which is California's share of the Colorado River supply according to the Supreme Court allocation.

The category labeled "Local Water Projects" includes local agency and federal surface water developments, except for Colorado River and Central Valley Project sources. It also includes water supplies from waste water reclamation and desalting, which are too small to show as a separate category.

Effect of Water Rights Decisions on Water Supply

Three recent water rights decisions by the State Water Resources Control Board will significantly affect the water supply outlook in California. These are Decision 1379, which establishes water quality standards for fishery, agricultural, and urban uses in the Sacramento-San Joaquin Delta; Decision 1400, which requires reservoir releases to enhance fishery and recreational benefits in the American River between Folsom Dam and Sacramento; and Decision 1422, which limits the amount of water to be stored in New Melones Reservoir on the Stanislaus River.

Table 17. Summary of 1972 and Projected Water Supplies, Net Water Demands and Supplemental Demands by Hydrologic Study Areas—Continued

(1,000 Acre-feet Per Year)

Items	San Joaquin Basin			Tulare Basin			North Lahontan			South Lahontan			Colorado Desert			State totals		
	1972	1990	2020	1972	1990	2020	1972	1990	2020	1972	1990	2020	1972	1990	2020	1972	1990	2020
Dependable water supplies																		
Local surface water developments	2,230	2,280	2,280	2,220	2,220	2,220	330	330	330	30	40	50	--	--	--	9,310	9,560	9,810
Imports by local water agencies	--	--	--	--	--	--	11	11	11	--	--	--	--	--	--	2,450	1,660	1,660
Ground water safe yield	520	520	520	510	510	510	56	90	110	120	130	130	74	85	90	5,220	5,470	5,560
Central Valley Project[1]	1,720	1,940	1,940	2,660	2,890	2,890	--	--	--	--	--	--	--	--	--	7,290	8,930	9,230
Other federal water developments[1]	0	48	48	240	240	240	--	--	--	--	--	--	3,950	3,970	3,970	5,110	5,310	5,310
State Water Project[2]	9	9	9	790	1,410	1,410	--	--	--	34	220	220	14	85	91	1,160	4,420	4,460
Waste water reclamation	26	38	62	45	59	85	6	9	12	7	8	10	7	9	12	180	290	360
Desalting	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	16	16
Total dependable water supplies	4,510	4,840	4,860	6,470	7,330	7,360	400	440	460	190	400	410	4,040	4,150	4,160	30,700	35,700	36,400
Alternative Future I																		
Total net water demand	4,650	5,510	6,280	7,300	9,200	11,000	430	450	480	280	330	510	4,070	4,240	4,430	31,000	38,300	46,000
Supplemental demand	250	670	1,420	1,310	1,920	3,640	40	20	20	120	3	100	40	90	270	2,450	3,810	9,610
Reserve supply[3]	110	0	0	480	50	0	10	10	0	30	70	0	10	0	0	2,140	1,200	0
Alternative Future II																		
Total net water demand	4,650	5,350	5,710	7,300	8,800	10,110	430	450	470	280	330	430	4,070	4,180	4,300	31,000	36,900	42,600
Supplemental demand	250	510	850	1,310	1,500	2,750	40	20	10	120	3	70	40	30	140	2,450	2,880	6,600
Reserve supply[3]	110	0	0	480	30	0	10	10	0	30	70	50	10	0	0	2,140	1,670	430
Alternative Future III																		
Total net water demand	4,650	5,120	5,320	7,300	8,290	9,160	430	450	470	280	320	370	4,070	4,150	4,290	31,000	35,400	39,700
Supplemental demand	250	280	460	1,310	1,030	1,800	40	20	10	120	3	30	40	20	130	2,450	2,070	4,420
Reserve supply	110	0	0	480	70	0	10	10	0	30	80	70	10	20	0	2,140	2,330	1,120
Alternative Future IV																		
Total net water demand	4,650	4,960	5,030	7,300	8,180	8,700	430	420	420	280	300	290	4,070	4,140	4,210	31,000	34,400	36,400
Supplemental demand	250	130	170	1,310	920	1,340	40	20	0	120	3	10	40	10	60	2,450	1,620	2,620
Reserve supply[3]	110	10	0	480	70	0	10	40	40	30	100	130	10	20	10	2,140	2,900	2,680

[1] Facilities existing or under construction; amounts include water rights and exchange supplies in the Central Valley furnished from CVP facilities.
[2] Facilities definitely planned for construction and additional conservatioo facilities authorized to meet contractual commitments.
[3] Potentially available to certain portions of the hydrologic study area to meet additional water demands; usually not available to other areas of supplemental demand because of a lack of physical facilities and/or institutional arrangements.

Decision 1379

Decision 1379 requires significantly higher outflows from the Delta than those contemplated in previous planning for both the Central Valley Project and State Water Project. Under these conditions, the combined yield of the Central Valley Project and State Water Project would be about 1.8 million acre-feet less than previously planned. The decision will be reviewed by the State Water Resources Control Board no later than July 1978. Recent guidelines for water quality management planning issued by the State Board indicate that the required outflow for fishery uses might be reduced during years of below-normal runoff. Water supply yields used in this report are based on assumed dry year relaxations which would reduce the 1.8 million acre-feet to 0.6 million acre-feet.

Decision 1400

In Decision 1400 (April 1972) the State Board established minimum requirements for fishery and recreation uses in the reach of the American River that flows through the Metropolitan Sacramento Area. Release from Folsom Reservoir would provide flows of 1,250 cubic feet per second (cfs) for fisheries and 1,500 cfs for recreation from mid-May to mid-October in all but dry years. These were considered the minimum flows that would provide a good in-stream fishery and recreation enhancement.

The previous fishery releases requirements were based on an agreement with the Department of Fish and Game negotiated when Folsom Dam was built. Fishery releases amounted to about 234,000 acre-feet per year, 250 cfs from January to mid-September and 500 cfs the rest of the year. The increased requirement under Decision 1400, about 750,000 acre-feet per year, reduces the quantity of firm water supply available for diversion at the head of Folsom South Canal.

Decision 1422

In Decision 1422 concerning the New Melones Project on the Stanislaus River, the State Board restricted water storage in the federal reservoir to that required to provide (a) for prior rights at existing Melones Reservoir, (b) up to 98,000 acre-feet per year for preservation and enhancement of downstream fisheries and wildlife habitat, and (c) additional water to maintain dissolved oxygen in the Stanislaus River and provide water quality control in the lower San Joaquin River at Vernalis.

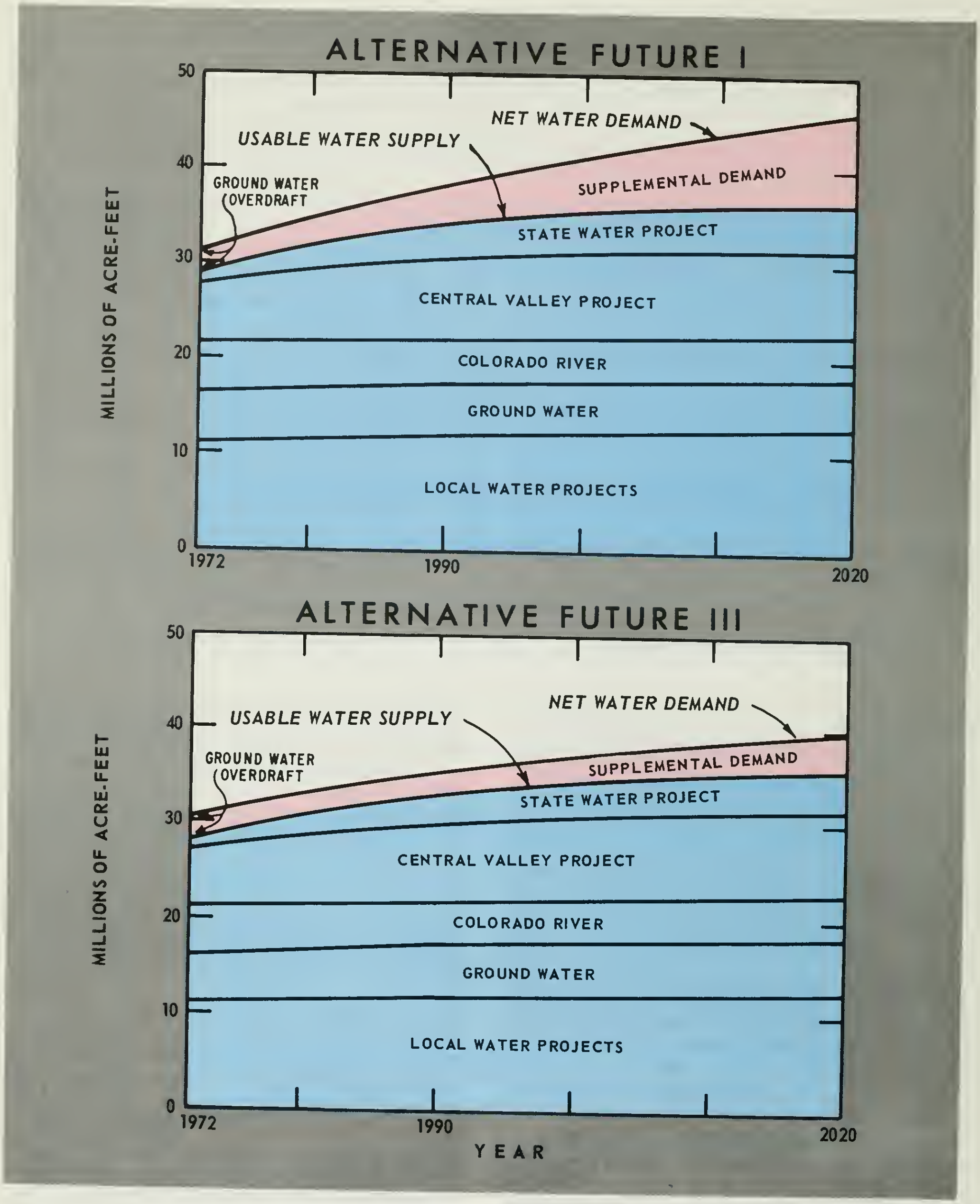


Figure 7. Statewide Water Demand and Usable Water Supply Summary

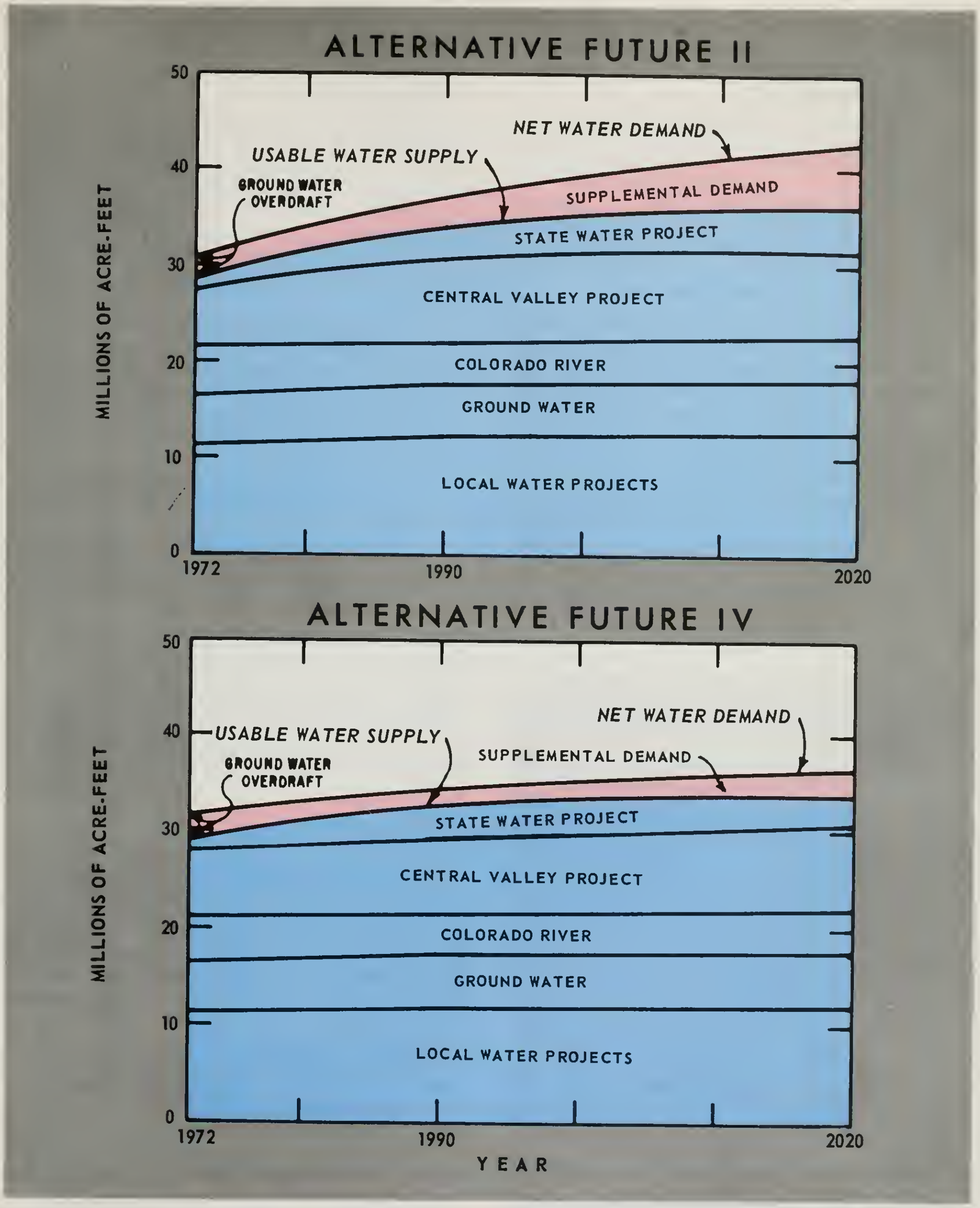


Figure 7. (Continued)

The decision, which will be reviewed by the State Board when there is a demonstrated need for more water for downstream uses, will preserve a popular "white water" area.

In effect, Decision 1422 limits water supply storage to about 30 percent of the New Melones total capacity of 2.4 million acre-feet. This will reduce firm water supplies by about 210,000 acre-feet, with substantial loss of electric power from the planned 300-megawatt hydroelectric plant and substantially reduced water levels in the reservoir for recreation.

Supplemental Water Demands

The supplemental water demands shown in Table 17 are the difference between the net water demand in each hydrologic area and that portion of the dependable water supply that is usable in the area of need. The determinations of supplemental demands include reserve supplies that cannot be readily used in areas of local water deficiency.

As shown in Table 17, the present (1972) statewide supplemental demands total about 2.45 million acre-feet per year, almost all of which is ground water overdraft, principally in the Central Valley. Depending on population, agricultural, and energy growth rates, future supplemental demands are expected to range from 1.6 to 3.8 million acre-feet in 1990, and from 2.6 to 9.6 million acre-feet in 2020.

Analysis of Central Valley Project and State Water Project Capabilities and Demands

Both the Central Valley Project and the State Water Project provide major transfers of water from areas of water surplus to areas of water deficiency. Because these two integrated projects account for much of the present water service and are expected to provide a greater share of the future water service, the capabilities of the two systems are significant in the analysis of California's water supplies.

Project Water Supplies

The estimated capability of the Central Valley Project to (a) meet prior water rights and exchange-water-service contracts, and (b) provide for the projected net demands computed for this report is about 9.2 million acre-feet per year. This assumes completion of Auburn and New Melones Reservoirs and the Peripheral Canal in the Delta, and reuse of return flows from some service areas.

The current sustained-yield capability of the existing State Water Project conservation facilities, together with the Peripheral Canal, will be about 3.4 million acre-feet. About 1 million acre-feet of additional authorized conservation capability will be added to meet contractual demands plus conveyance losses, which together total 4.46 million acre-feet.

The Peripheral Canal

In 1959, the State Legislature recognized in the Burns-Porter Act that some kind of physical works would have to be built to transfer Sacramento River water through the Delta and concurrently to solve water quality and fishery problems within the Sacramento-San Joaquin Delta. In 1964, the Peripheral Canal was recommended as the best plan for the Delta, and was the most flexible of all proposed Delta plans. It would:

- Protect and enhance the Delta fishery by restoring downstream flows in Delta channels.
- Provide water quality control for the interior Delta uses by releasing water from many outlets.
- Correct a deteriorating environmental condition by isolating project pumps from the Delta channels.
- Improve Delta recreation by providing new facilities along the Canal and by improving Delta access.
- Ensure the quality of the water supply needed by agriculture, industry, and millions of Californians west and south of the Delta served by the state and federal projects.

Although the Peripheral Canal was planned as a federal-state project, federal participation may not be authorized in time to complete the Canal by 1980, when it will be needed. Accordingly, the State has been preparing to proceed with a staged construction plan; this will enable participation by the U. S. Bureau of Reclamation as soon as federal authorization is obtained.

Water Demands on the Central Valley Project

In the Central Valley Project service areas, estimated 1972-level water demands and projected future water demands that could be fulfilled by the project works, either existing or under construction, are summarized in Table 18. These projections are based on the assumption that Folsom-South Canal will be completed into San Joaquin County and that New Melones Reservoir will serve areas of need in the San Joaquin Hydrologic Study Area.

Table 19 summarizes the additional water supply demands in the Central Valley Project service areas that would occur under each alternative future. In effect, these additional demands represent that portion of the supplemental water demand that lies within or adjacent to the Central Valley Project service areas and exceeds the service areas commitments. Figure 8 graphically depicts the water supply and demand picture of the Central Valley Project.

Table 18. Net Water Demands on the Central Valley Project [a]
(1,000 acre-feet)

Hydrologic study area	1972	1990 Alternative future I	1990 II	1990 III	1990 IV	2020 Alternative future I	2020 II	2020 III	2020 IV
San Francisco Bay	60	100	90	90	80	270	210	180	110
Sacramento Basin	2,090	3,050	2,900	2,720	2,660	3,490	3,270	2,930	2,810
Delta-Central Sierra	90	840	730	570	520	900	910	910	800
San Joaquin Basin	1,620	1,940	1,940	1,940	1,930	1,940	1,940	1,940	1,940
Tulare Basin	2,180	2,840	2,850	2,820	2,810	3,040	3,040	3,040	3,020
Total	6,040	8,770	8,510	8,140	8,000	9,640	9,370	9,000	8,680

[a] Up to authorized commitments upon facilities existing or under construction.

Table 19. Possible Additional Demands on the Central Valley Project [a]
(1,000 acre-feet)

Hydrologic study area	1990 Alternative future I	1990 II	1990 III	1990 IV	2020 Alternative future I	2020 II	2020 III	2020 IV
San Francisco Bay	50	50	40	20	190	180	160	70
Central Coastal	80	80	80	80	110	110	110	110
Sacramento Basin	400	310	230	190	770	580	430	280
Delta-Central Sierra	150	110	100	80	760	540	380	220
San Joaquin Basin	670	500	280	120	1,360	800	450	170
Tulare Basin	1,550	1,290	980	910	2,690	2,110	1,410	1,130
Total	2,900	2,340	1,710	1,400	5,880	4,320	2,940	1,980

[a] In addition to authorized commitments upon facilities existing or under construction.

New facilities that could provide additional water supplies to Central Valley Project service areas to meet the additional water requirements shown in Table 19 are:

Feature	To serve these Hydrologic Areas (see Figure 1)
1. San Felipe Division*	SF and CC
2. Marysville Reservoir*	SF, CC, SB, DC, SJ and TB
3. West Sacramento Canal†	SB, DC, and SF
4. Mid-Valley Canal†	SJ and TB
5. East Side Division†	SJ and TB
6. Allen Camp†	SB
7. Cosumnes River Division†	DC

* Authorized
† Not authorized

Water Demands on the State Water Project

Demands for service from the State Water Project are increasing rapidly now that the initial facilities are in operation. One factor tending to increase State Water Project demands in Southern California is the better quality of Northern California water compared with Colorado River water, with its relatively high content of dissolved salts. Additional supplies will be needed in the 1980s, when Colorado River supplies

Wind Gap Pumping Plant—State Water Project

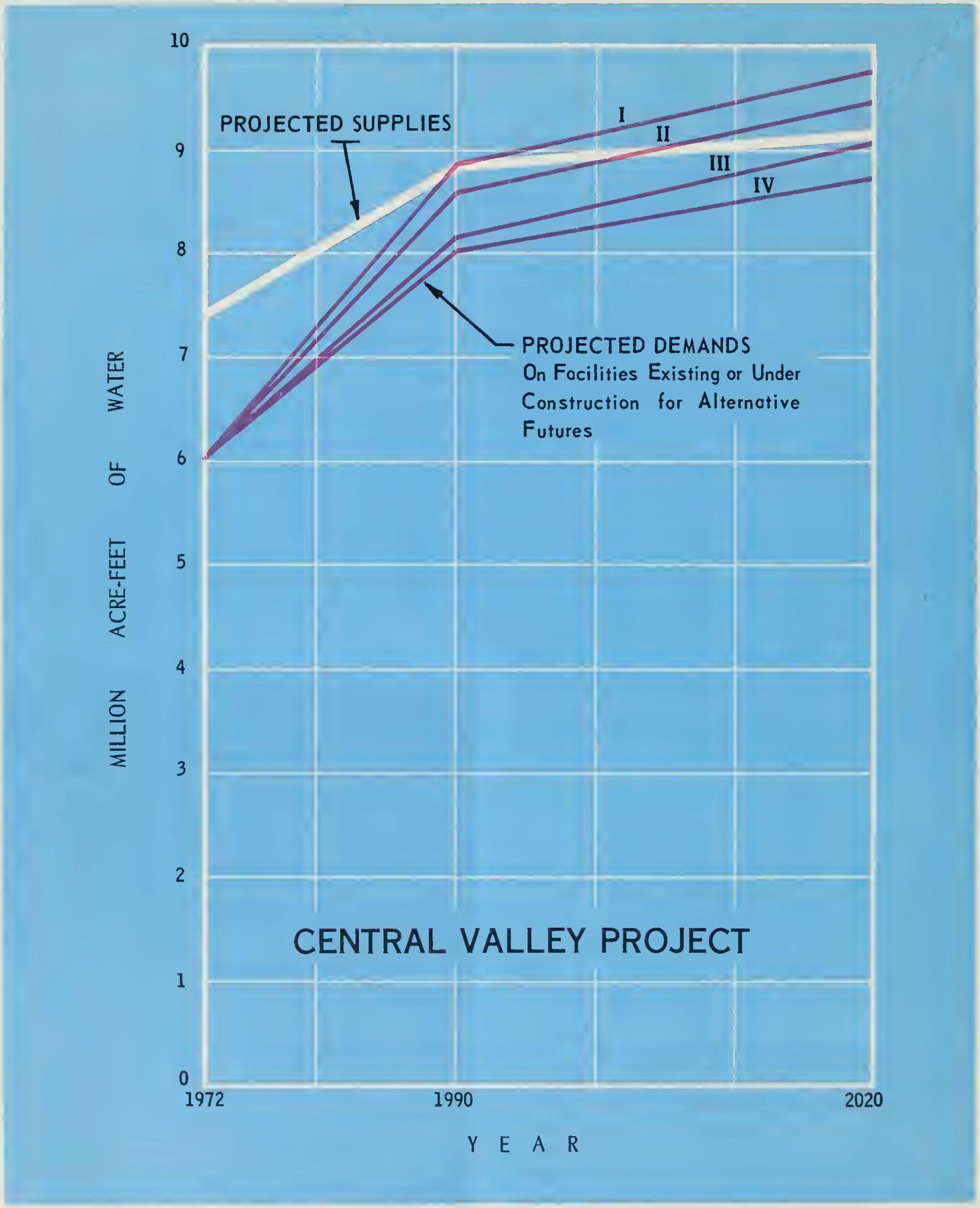


Figure 8. Projected Net Water Demands and Dependable Water Supply—Central Valley Project

delivered to the South Coastal area are reduced when the Central Arizona Project begins to use more of Arizona's entitlement to Colorado River water.

State Water Project demands in this report are based on the assumption that the North Bay Aqueduct and Coastal Branch, as well as the necessary final pumping units at both the Delta and Edmonston Pumping Plants, will be completed. Projected demands, including recreation water and conveyance losses, are as shown in Table 20.

Table 20. Net Water Demands on the State Water Project Under Present Contracts (1,000 acre-feet)

Hydrologic study area	1972	1990 Alternative future I	1990 II	1990 III	1990 IV	2020 Alternative future I	2020 II	2020 III	2020 IV	Maximum[1] annual entitlement
San Francisco Bay	130	200	200	200	200	260	260	260	240	260
Central Coastal	0	90	90	90	90	90	90	90	90	90
South Coastal	100	1,690	1,620	1,560	1,310	2,340	2,340	2,340	1,370	2,340
Sacramento Basin	0	40	40	40	40	40	40	40	40	40
San Joaquin Basin	10	10	10	10	10	10	10	10	10	10
Tulare Basin	790	1,410	1,410	1,410	1,410	1,410	1,410	1,410	1,410	1,410
South Lahontan	0	160	150	150	130	220	220	200	110	220
Colorado Desert	0	80	80	80	80	90	90	90	90	90
Total	1,030	3,680	3,600	3,540	3,270	4,460	4,460	4,440	3,360	4,460

[1] Includes recreation water and conveyance losses.

Additional demands for State Water Project service are expected in areas now served by the project and in areas immediately adjacent to the present service areas. Satisfaction of these demands would require additions to the presently authorized State Water Project conveyance system. The estimates of possible future demands shown in Table 21 are based on a limit of 880,000 acre-feet additional service to Southern California. This is the estimated additional capacity of the tunnels through the Tehachapi Mountains. However, enlargement of the Edmonston Pumping Plant and many sections of the California Aqueduct north of the Tehachapi would be required to convey that much additional water. Additional conservation facilities would also be required to increase the water supplies of the project.

Comparison of Supply and Demand

Figure 9 shows a comparison of the State Water Project supply and net demands for each of the four alternative projections. The demand lines for the first two alternative futures level off when they reach the amount under contract because the figure depicts the Project as presently planned. The supply line is the estimated capability of existing State Water Project conservation facilities.

Much of the information presented in this bulletin is based on statewide data. Data on projected population growth, water demands, and water supplies are presented to show statewide totals. For those who require more detailed information, data on the water supply—water demand relationship in each hydrologic area are presented in Chapter VI of the full report.

Table 21. Possible Demands on the State Water Project in Addition to Present Contracts (1,000 acre-feet)

Hydrologic study area	1990 Alternative future I	1990 II	1990 III	1990 IV	2020 Alternative future I	2020 II	2020 III	2020 IV
San Francisco Bay	10	10	10	0	120	80	60	20
Central Coastal	40	20	10	10	100	90	70	40
South Coastal	0	0	0	0	610	300	60	0
San Joaquin Basin	0	0	0	0	40	30	0	0
Tulare Basin	370	210	60	10	800	500	240	80
South Lahontan	0	0	0	0	80	50	20	0
Colorado Desert	70	10	0	0	190	70	70	20
Total	490	250	80	20	1,940	1,120	520	160

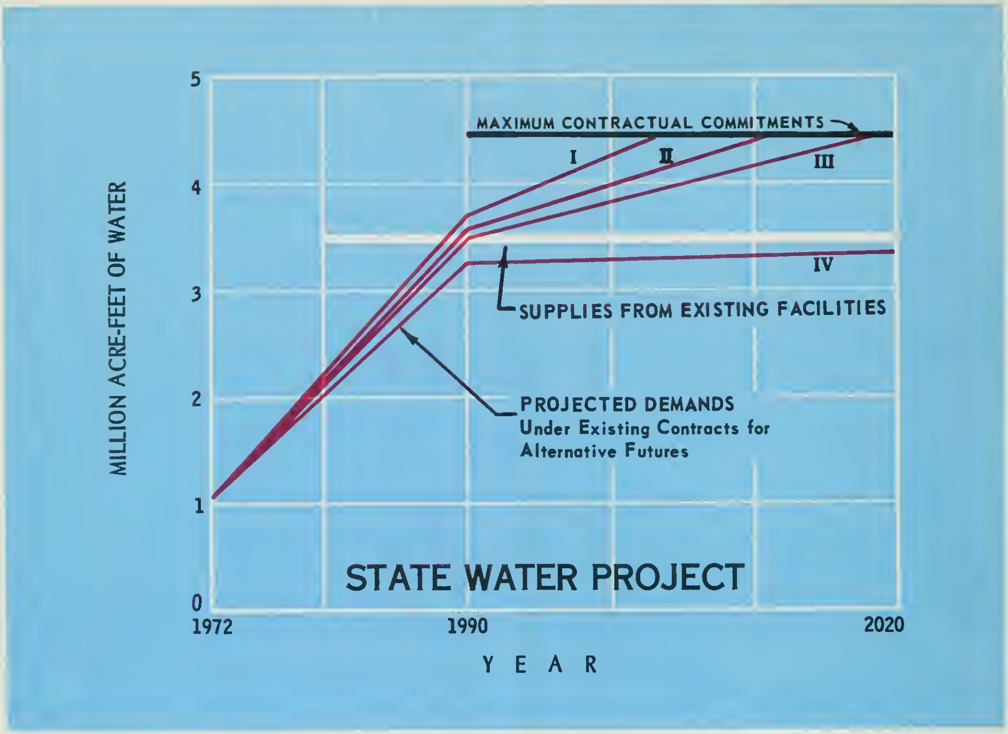


Figure 9. Projected Net Water Demands and Dependable Water Supply—State Water Project

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